EFFECT OF IMPLANT HEIGHT DIFFERENCES ON THE RETENTION AND WEAR BEHAVIOUR OF BALL ATTACHMENT SYSTEM IN MANDIBULAR TWO-IMPLANT OVER DENTURES - AN *IN VITRO* STUDY

Dissertation Submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH I

PROSTHODONTICS AND CROWN & BRIDGE

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled "**EFFECT OF IMPLANT HEIGHT DIFFERENCES ON THE RETENTION AND WEAR BEHAVIOUR OF BALL ATTACHMENT SYSTEM IN MANDIBULAR TWO-IMPLANT OVER DENTURES - AN *IN VITRO* STUDY**" is a bonafide and genuine research work carried out by me under the guidance of **Dr.Vidhya J, M.D.S.,** Reader , Department of Prosthodontics and Crown & Bridge, Ragas Dental College and Hospital, Chennai.

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This dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the Degree of **MASTER OF DENTAL SURGERY – PROSTHODONTICS AND CROWN & BRIDGE, BRANCH I.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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PLAGIARISM REPORT

Introduction

INTRODUCTION

Edentulism is considered as a poor health outcome and it often compromises the quality of life of edentulous people.[34] Complete edentulism is a condition that is most prevalent among the elderly population.[34,42] It has a negative impact on the masticatory function, speech, esthetics and on the quality of life. The prosthetic management of the completely edentulous patient has been a major challenge in dentistry.[2.28] Conventional complete denture have been a standard and classical treatment option for the completely edentulous patients for more than a century.[2.24,34]

Conventional complete denture is commonly provided to completely edentulous patients to restore masticatory function and esthetics.[24,34] The complete denture wearers often encounter problems like difficulty in mastication, discomfort during speech along with poor stability and retention.[24,26,34] They are usually satisfied with the upper denture but the majority of them often struggle with the lower denture due to the lack of retention and stability.[19,34]

Alveolar ridge resorption is one of the important factor which is associated with loss of stability and retention in lower denture. It also reduces the amount of underlying tissue available for denture support.[19,34] The resorption of the residual alveolar ridges is a chronic, continuous, life-long catabolic process of bone remodelling. The rate of reduction in size of the residual ridge is maximum in the first three months and then gradually tapers off.[32]

According to Boucher, during the first year after tooth extraction, the reduction in the residual ridge height in the mid sagittal plane is 2-3mm for maxilla and 4-5mm for mandible and the annual rate of reduction in ridge height is 0.1- 0.2mm for mandible and this reduction in height of the ridge is four times less in the maxilla.[31,32,34]

Many studies have shown that the poor retention and stability could be managed using a fixed prosthesis supported by five or six implants or by the fabrication of an overdenture to implants.[31] However, placing six implants in an atrophic mandible is not always possible. Therefore, the concept of using two or four implants to support an overdenture was introduced.

Overdenture is a therapeutic approach which is directed in improving the oral function in elderly edentulous patients.[11] The concept of overdenture initially involved fixing mechanical attachments to teeth roots to enhance retention and stability of conventional complete dentures.[26,31] With the evolution of implant overdentures , there is reduction in displacement of the prosthesis due to lateral forces leading to better retention and stability improving the masticatory function and overall quality of life .[4,17,24] Crum and Rooney[32] reported an average of 5.2mm loss in the alveolar ridge height in denture patients compared to overdenture patients where there is 0.6mm loss which is relatively low.

According to McGill consensus, two-implant overdentures has been accepted as the gold standard treatment care for the edentulous mandible.[12,24] Various factors contribute to the success of an implant supported overdentures, including the fit and precision of dentures and the retentive capacity of its attachment system to provide long duration of function. Therefore, Retention is considered as one of the most significant factors in determining patient satisfaction in removable prosthodontics[10,31] and is defined as the force that resists withdrawal along the path of insertion and stabilizes the overdenture during its function.[10,30]

Also, the choice of attachment is primarily dependent on the retention required, jaw morphology and anatomy, condition of the mucosal ridge, oral function and patient compliance for recall appointments. There are different attachments to retain implant supported overdentures. They were classified on the basis of their flexibility, geometrical shape and cross section, casting precision and manufacturing procedures. In one of the major classifications, these attachments are divided into splinted and unsplinted systems. Splinted systems includes the bar attachments whereas unsplinted systems includes magnets, ball types and locators.[5,19,24,36]

Within these systems, self-aligning attachments (locators) and ball attachments have been frequently used due to their simplicity. Specifically, ball attachments are considered as one of the simplest type of attachments for clinical usage. It provides varying degrees of resiliency in both vertical and horizontal directions. Also, the specific design of the ball attachments may influence the amount of its free movement thereby limiting its resiliency.[4,24,34,41]

The retention and the longevity of the attachments have been studied as a common problem in many clinical and in vitro studies. There are lot of studies evaluating the retentive force of different attachment systems in mandibular two-implant overdentures simulating different periods of clinical usage.[4,19,26,35] Some studies have comparatively evaluated the retention capacity of ball ,bar and locator attachments in implant overdentures.[35] Studies have also compared retention between locator, ball and magnetic attachments.[43]

Many studies have compared the retentive capacity of different color codings of a single attachment system.[10,37,] Few authors have studied the retentive forces of the attachments by placing implants at different angulations.[10,43]

Previous studies have evaluated the retentive force using micro material testing machine(MTM),[30,31] a dental mastication simulator,[10,37] CS-

Dental testing machine,[5] load cell (cyclic fatigue machine),[9] Imada device (IM)[16,18] and Universal testing machine(UTM) [4,18,26] and among these methods Universal testing machine (UTM) has been accepted as reliable and valuable instrument to test the retention forces *in vitro.*[4,26]

One of the main factors of retention loss is the change induced on the components of the attachment systems as a result of wear.[4,26] The factors which are associated with the clinical wear of attachments includes masticatory forces, parafunctions, temperature and composition of saliva, products used for the maintenance of denture and the presence of food residues.[9] The wear of overdenture retentive mechanisms has been identified as the most common prosthodontic complications which is about 33%.[42]

In addition to the retentive forces, few studies have also evaluated the amount of wear and its effects in the attachment systems. Wear have been assessed using Metallographic microscope,[27] Micro material testing machine (MTM),[3,25,29,30]Coordinate measuring machine (CMM),[41] Scanning electron microscopy(SEM),[10,21] and stereo microscopy.[26,36]

The positioning of the implant overdenture attachments is very important for two-implant overdentures .This is because during pathological overloading, the bone around the implants becomes deformed and resorbed due to the increased stress and strain gradients.[24] This situation may cause incompatibility of the components of the implant system and microfracture of the implant.[24]

Clinicians predicted that the two independent implants must be positioned at the same occlusal height, parallel to the occlusal plane.[18] However, placement of implants in the same occlusal height in completely edentulous patient is not always possible since the alveolar bone resorbs with different types of resorption patterns.[24] The rate of residual ridge resorption differs from person to person and even at different times and sites in the same person. Unlike in maxilla, the speed of bone loss in mandible is different in different parts of the jaw, distal parts of the residual ridge disappear faster than the anterior parts, which may affect the symmetry of the remaining bone height resulting in difficulty in placing the implants in position.[32]

Few studies have evaluated the retention force of attachment systems retained by single or two implants[22] and also at different abutment heights.[37] Ozan O and Ramoglu S have compared two different attachment systems in two-implant overdentures by evaluating the stress distribution in peri-implant site and on attachments by positioning implants in different height levels using the 3D Finite Element Analysis method.[24] Currently, studies comparatively evaluating the retention and wear behaviour of two-implant overdenture attachments with implants positioned at different height levels are lacking.

In light of the above, the aim of the present *in vitro* study was to evaluate the effect of implant height differences on the retention and wear behaviour of ball attachment system in mandibular two-implant overdentures.

The null hypothesis for the present study was that implant height difference does not affect the retention and wear behavior of the two-implant overdenture attachments.

Also glued to the aim were the following objectives:

1. To evaluate the retention force of overdenture specimen with ball attachment system retained by two implants placed in the same height at baseline, at 360(3 months), 720(6 months), 1080(9 months) and after 1440(12 months) insertion-removal cycles in Group I.
2. To evaluate the retention force of overdenture specimen with ball attachment system retained by two implants placed in different height at baseline, at 360(3 months), 720(6 months), 1080(9 months) and after 1440(12 months) insertion-removal cycles in Group II.
3. To comparatively evaluate the retention force of all the test samples at baseline, at 360(3 months), 720(6 months), 1080(9 months) and after 1440(12 months) insertion-removal cycles between Groups I and II.
4. To comparatively evaluate the retention force of all the test samples at baseline, at 360(3 months), 720(6 months), 1080(9 months) and after 1440(12 months) insertion-removal cycles within Group I.

5. To comparatively evaluate the retention force of all the test samples at baseline, at 360(3 months), 720(6 months), 1080(9 months) and after 1440(12 months) insertion-removal cycles within Group II.
6. To evaluate the percentage loss of the mean retention force of the test samples at 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion-removal cycles in Group I.
7. To evaluate the percentage loss of the mean retention force of the test samples at 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion- removal cycles in Group II.
8. To qualitatively evaluate the wear of the attachments of all the test samples at baseline and after completion of 1440 insertion-removal cycles in Group I.
9. To qualitatively evaluate the wear of the attachments of all the test samples at baseline and after completion of 1440 insertion-removal cycles in Group II.

Review of Literature

REVIEW OF LITERATURE

Botega et al (2004)[8] evaluated the retention force and fatigue resistance of two overdenture attachment systems like O-ring and Bar-Clip from two manufacturers .They were submitted to mechanical fatigue test using a servohydraulic machine performing 5500 cycles of insertion and removal (f = 0.8 Hz), immersed in artificial saliva. Retention force values were obtained three times (0, 3000 and after 5500 cycles) simulating the clinical service, using a tensile strength at 1 mm/ min and load cell of 1 kN. The systems evaluated showed satisfactory retention force values, before and after fatigue testing. A 5-year simulation of insertion and removal did not decrease retention values or fracture components.

Rutkunas V (2004)[28] evaluated the fatigue of stud (orange and white), Locator (pink) and magnetic attachments by measuring maximum retentive force and compared the retentive force of overdenture and also determined the minimum number of cycles required to reach stable retention. Micromaterial testing Machine with a sensor interface and software package was used to perform 2000 insertion-removal cycles with 50 mm/min cross head speed. Results showed that before and after fatigue simulation, statistically significant differences existed between all the attachments. Decrease of retention was characteristic for all attachments except locator attachment. It was concluded that due to fatigue, overdenture attachments gradually lose their retention and the stud attachments are more susceptible to fatigue than magnets.

Amarsanaa B et al (2008)[3] evaluated and compared the maximum stabilizing force and stabilizing energy of mandibular overdentures with several attachments during anterior, lateral and posterior dislodgement before and after wear simulation. Changes in the maximum retentive force and maximum stabilizing force of each attachment during various levels wear simulation were also examined. It was concluded that maximum stabilizing force and stabilizing energy can each be used to evaluate the stability of overdentures. Both parameters were different during anterior, lateral and posterior dislodgement after and before wear simulation.

Pigozzo MN et al (2009)[25] evaluated the retentive strength and fatigue resistance of 4 overdenture bar-and clip attachment systems. Specimens immersed in artificial saliva were tested to 5500 cycles at 0.8 Hz using a servohydraulic universal testing machine. Retention strength values (N) were recorded initially and after 1100, 2200, 3300, 4400, and 5500 insertion and removal cycles during the tensile test using a speed of 1 mm/min and a load cell of 1 kN. The results were an increase in retention strength values was observed during the fatigue test after 5500 cycles of insertion and removal. The systems evaluated demonstrated satisfactory retention for all time periods tested, as retention strengths from 5 to 7 N should be sufficient to stabilize overdentures. No component fracture or compromise in retention was found for any of the systems tested.

Rodrigues et al (2009)[27] evaluated the retention force of an O-ring attachment system in different inclinations to the ideal path of insertion, using devices to compensate angulations. Cylinders with O-ring s were placed on ball attachments and connected to the test device using positioners to compensate implant angulations (0, 7, and 14 degrees). A total of 2900 cycles, simulating 2 years of overdenture use, were performed and 36 O-ring s were tested. The force required for each cycle was recorded with computer software. It was concluded that O-ring s for implant/attachments perpendicular to the occlusal plane were adequately retentive over the first year and that the retentive capacity of O-ring was affected by implant inclinations despite the proposed positioners.

Yang TC et al (2011)[43] evaluated the retentive force and lateral force of an implant with various types of attachments for overdentures in relation to implant inclination. It was concluded that the retentive force decreases with an increase in the implant inclination.

Rutkunas V et al (2011)[30]evaluated wear effects on overdenture resilient attachments. Six commercially available attachments were investigated: ERA orange and white (EO and EW), Locator pink, white and blue (LRP, LRW and LRB) and OP anchor (OP). Five specimens were used for wear simulation while other two specimens served as controls. Fifteen thousand insertion-removal cycles were simulated. Dimensional changes and surface characteristics were evaluated using light microscopy and SEM, respectively. Sudden decrease of retentive force was characteristic for EO and EW attachments. Retentive force of Locator attachments fluctuated throughout the wear simulation period. Dimensional changes and surface wear was more expressed on plastic cores than on plastic rings of attachment males.

Guttal S (2012)[17] tested the retention strength and fatigue resistance of Rhein OT cap and Ceka sagix attachment systems. The retention strength was measured at various cycles like 1,440, 2,880, 4,320 and 5,760 cycles to the loss of retention and development of fatigue on the basis of average number of removals and placements per day for1, 2, 3 and 4 years, respectively. The results obtained proved that the retention values of both the attachment systems on tooth supported overdentures had a significant variation as they were subjected to increased number of cycles. It was also concluded that fatigue test simulating 4 years of denture insertion and removal did cause subsequent reduction in the retention values but no component fracture of attachment systems.

Kobayashi M et al (2013)[19] compared the change in retentive force and removal of three attachment systems during the simulation of insertion-removal cycles. Locator, spherical Dalbo-PLUS and SFI-Bar-attachments on Straumann RN Implants were used. Testing was carried out with an universal testing machine for a total of 14,600 insertion-removal cycles in 0.9% sodium chloride solution. Results showed that, initially all three attachment systems demonstrated increasing retentive forces. From cycle 5000 on, Locator attachments showed lower mean retentive forces than the Dalbo-PLUS and SFI-Bar-groups. The Dalbo-PLUS and SFI Bar-attachments showed a steady yet not significant increase during the whole observation period. Implant-angulation had no significant influence on the retention forces. The final mean removal torques were significantly reduced.

Carvalho ER (2014)[9] evaluated the retentive force of two attachments and their respective connection systems in a mandibular implant-supported overdenture. A specific machine was designed to measure the retentive force of the attachments over the cycles applied. The speed of insertion/disinsertion was 0.5 Hz, applied constantly. It was concluded that the initial retention force decreases over time for the attachment systems tested.

Jalalian S et al (2015)[18] evaluated the effect of disto-labial inclination of implant and attachment on retention and longevity of implant-supported overdentures. Analogues were placed at disto-labial inclinations of 5, 10 and 15 degrees. The maximum initial retention before thermo-cycling was found in specimens with 5 degrees of inclination. After thermo-cycling, the maximum retention was found in specimens with 15 degrees of inclination. The minimum retention was recorded in the group with 10 degrees of inclination in both condition . Inclination of implant and attachment has a positive effect on the retention and longevity of overdenture in a way that by increasing the inclination to 15 degrees, the retention increases but wear-down rate and retention loss also increase simultaneously.

Ozan O and Ramoglu S (2015)[24] compared two different attachment systems in a two-implant overdenture by evaluating the stress distributions in the peri-implant bone and stresses on the attachments with implants positioning at different height levels using the 3D Finite Element Analysis method. The configurations in which implants presented with 3mm height difference in the bone level showed the most successful results in the peri-implant bone. On the contrary, the peak stress values around the implant observed from the models with less (1mm) bone height difference require levelling of the bone during surgery.

Reda KM et al (2016)[26] compared the retention force of three different types of overdenture attachment systems used in implant-retained mandibular overdentures. Snap, syncone and locator attachments were used for the retention force measurement, subjecting to 5500 cycles of insertion and removal in the presence of artificial saliva, representating 5 years of clinical usage in universal testing machine. The results showed that the locator attachments showed greatest retention throughout the study followed by snap attachment and the syncone attachment showed the lowest retention level. It was concluded that regardless of the initial retention level of the overdenture attachments, gradual loss of retention was inevitable.

Vafaee et al (2016)[41] assessed the wear of matrix in overdentures attachment supported by one, two and three implants in the mandible. The matrix wear was measured with CMM (Coordinate Measuring Machine) device. Results showed that the lowest mean matrix wear in the maximum single implant and maximum mean were in group two and also this study concluded that both time and the number of implants had a significant effect on the wear of the overdenture attachments.

Shastry T et al (2016)[35] compared the change in the retentive force and removal torque of three attachment systems during simulation of insertion-removal cycles. Prefabricated ball/O-ring attachment, Hader bar and clip attachment, and Locator attachment were used and the retention test was performed using a universal testing machine. It was concluded that the ball/ O-ring and bar attachments developed higher retentive force as compared to the locator attachment. Also the bar and clip attachment exhibited the highest peak as well as the highest mean retention force at the end of the study and the Locator attachment showed a decrease in the retentive potential after an early peak.

Mattia PR et al (2016)[22] evaluated the retentive force of attachments in single implant-retained overdentures. Three attachment systems (ERA, O-ring, and Ball Attachment), using components made from different materials (plastic and metal), were tested under two different support conditions (single-implant or two-implant). They concluded that single-implant support for mandibular overdentures can be an alternative for the oral rehabilitation of fully edentulous patients, providing greater simplicity, lower costs, and similar retentive strength as compared to two-implant overdentures, improving the user's quality of life.

Aroso C (2016)[5] investigated and compared the durability and retention of three types of attachments. The abutments were placed at angulations of 0°, 10° and 20°. The retention force was recorded at the beginning and after 540, 1080, 2160, 3240, 4320 and 5400 insertion-removal cycles. The results revealed that there were significant differences in the average values of the insertion/removal force due to angulation and the type of attachment. It was also concluded that greater angulation of the abutments was found to influence the retention capacity of the attachments, and the fatigue test simulating 5 years of denture insertion and removal did not produce wear in the metal abutments.

ELsyad MA et al (2016)[15] evaluated and compared retentive properties of O-ring and Locator attachments(extra light , light and medium) for implant -retained maxillary overdentures. It was concluded that Locator medium attachment was associated with favorable retention during axial (vertical) and nonaxial (anterior and lateral) dislodging compared to other types of Locator inserts and O-ring attachments after a simulated 6-month period of overdenture use.

Savy Arora and Sanjeev Mittal (2017)[4] compared the retention force value of four different attachments of implant overdentures. Results showed that the Locator attachments were found to be most retentive among all the attachments used in the study. Maximum retention loss occurred for O-ring attachments. It was concluded that all the overdenture attachments lose their retention over time. However, the Locator attachment showed maximum retention values after simulating 1 year of clinical use in the universal testing machine.

Ying Z et al(2017)[44] evaluated the influence of overdenture attachments height and shape on implants and denture displacement. They concluded that to protect an implant supporting overdenture and to prevent bone resorption, the height of the attachment should be carefully considered.

Mermarian M et al (2018)[23] compared the retention of two dental implant systems with compatible ball attachments, namely Straumann system (SS) and Rhein83 SRL system (RS).The retention strength values (RSV) were recorded before the fatigue test and after 1100, 2200, 3300, 4400, and 5500 insertion and removal cycles at a speed of 51 mm/minute with a 50-N load cell in a universal testing machine. The result was a decrease in the RSV in both systems after 5500 cycles of insertion and removal. They concluded that although the RSVs of the RS and SS were almost similar before the fatigue test, as the number of insertion and removal cycles increased, the RSV decreased more significantly in the RS compared to the SS.

Tomas NM et al (2018)[39] studied the retentive force of two attachment systems like Locator and Equator subjecting them to 14,600 insertion and de-insertion cycles (representing 10 years functional life) in axial direction. The universal test machine crosshead speed was 50 mm/min with a de-insertion range of 2 mm. Both systems showed increased retention up to the first 1,000 cycles, which decreased thereafter up to 14,600 cycles. Both systems presented acceptable retention capacities after 14,600 cycles. Significant differences in retention force between the systems evolved after 7,500 cycles (5 years in vitro use).

Materials and Methods

MATERIALS AND METHODS

The present *in vitro* study was conducted to evaluate the effect of implant height differences on the retention and wear behaviour of ball attachment system in mandibular two-implant over dentures.

The following materials, instruments, equipment and methodology were employed:

Materials used for the study:

- Stainless steel implant analog - 4mm diameter and height 12.7mm

  (NORIS dental implants)(Fig.1)

- Titanium ball attachments - 2.5mm diameter and 2mm height (NORIS dental implants)(Fig.2)

- Stainless steel metal housing - 5mm diameter and height 3.2mm (NORIS dental implants)(Fig.3)

- Cap insert – standard , white , nylon (NORIS dental implants)(Fig.4)

- Polyvinyl siloxane impression material(Aquasil,dentsply, germany)

- Putty consistency polyvinyl siloxane impression material (Fig.5a)
- Light body consistency polyvinyl siloxane impression material (Fig.5b)
- Dispensing gun (Heraeus Kulzer, Dormagen, Switzerland) (Fig.5c)
- Auto mixing spiral (yellow 70mm, Adenta, USA)(Fig.5d)

- Modelling wax (Hindustan Dental Products, Hyderabad)(Fig.6)
- BP Blade and Handle (Glassvan,INDIA)(Fig.7)
- Artificial saliva(Fig.8)
- Plaster of paris (Ramaraju Mills ltd.,India) (Fig.9)
- Cold mold seal (DPI, India) (Fig.10)
- Clear heat polymerizing acrylic resin (DPI, India) (Fig.11)
- Clear autopolymerizing acrylic resin (RR cold cure, DPI, India)(Fig.12)
- Vaseline (Fig.13) (Tejpal pharma and surgicals)

Instruments used for the study:

- Rubber bowl and spatula (Classic, India) (Fig.14)
- Wax knife and wax carver (Dentex store, India)(Fig.15)
- Metal scale (Dentex store, India) (Fig.16)
- Bunsen burner (Star dental , India) (Fig.17)
- Porcelain mixing jar (Dentex store, India) (Fig.18)
- Dental flask with clamp (Star dental, India) (Fig.19)
- Acrylic trimmers (Shofu, Japan)(Fig.20)
- Sand paper mandrel (Dentex store, India) (Fig.21)
- Emery papers (Dentex store, India) (Fig.22)

Equipments used for the study:

- Dental surveyor (Saeshin precision Ind. Co., Korea) (Fig.23)
- Acrylizer (Confident dental equipments limited, Bangalore,India) (Fig.24)
- Dental lathe (Suguna industries limited, India)(Fig.25)
- Universal testing machine (Instron,8874 ,UK)(Fig.26)
- Stereo microscope (Olympus) (Fig.27)

Description of the universal testing machine:(Fig.26)

Universal testing machine (Instron 8874) was employed in the present study for obtaining the retentive values of the test samples. This machine is a bi-axial tabletop servohydraulic testing system providing a combined axial and torsion dynamic actuator in the upper crosshead.With a precision aligned twin-column frame and a lower t-slot table,this model meets the challenging demands of a varied range of both static and dynamic testing requirements.It performs multi-axial tests on materials or components provided. Both the upper and the lower member has hydraulic clamps to hold the test samples for performing the required action. The whole unit is attached to a computer for recording and converting the data.

Description of the stereo microscope: (Fig.27)

In this present study, the surface of the test samples was analysed using stereo microscope (Olympus), which offers efficient image acquisition, quantitative measurements and image analysis. It uses light source with real time on-screen imaging in a computer software controlled system. Designed for flexibility, the software has a broad scope of functions necessary to conduct fast, precise observations on a variety of samples while maintaining data security and reliability. It has a magnification of upto100x image enlarging rate.

METHODOLOGY

The present in *vitro* study was conducted to evaluate the effect of implant height differences on the retention and wear behaviour of ball attachment system in mandibular two-implant over dentures.

The methodology adopted in the present study is described under the following sections:

I. Fabrication of custom-made plaster of paris block (Fig.28)

II.Obtaining silicone putty index using custom-made plaster of

block (Fig.29)

III.Preparation of wax blocks using the index.(Fig.30a &30b)

a.Master wax blocks (n=2)

b.Prosthetic wax blocks (n=20)

IV.Placement of implant analogs in the master wax blocks.(Fig.31a & 31b)

V.Fabrication of heat polymerized acrylic resin blocks.(Fig.32a & 32b)

(Two Master blocks with implant analogues and Twenty Prosthetic blocks.)

a. Flasking procedure

b. Dewaxing procedure

c. Packing of acrylic resin

d. Curing procedure

e. Deflasking procedure

f. Finishing and Polishing

VI.Placement of ball abutments to the implant analogs in the master blocks (Fig.33)

VII.Placement of metal housing with nylon cap insert over the ball abutment.

(Fig.34)

VIII.Connecting the attachments to the prosthetic blocks.

a) Recesses prepared in the prosthetic blocks to pick up the attachments. (Fig.35a)

b) Incorporation of attachments into the prosthetic blocks (Direct Pick up technique)(Fig.35b).

IX.Grouping of the test samples (Fig.36)

X.Initial Qualitative analysis of the wear of surface of the attachments by stereo microscope.(Fig.37)

XI.Retention Force Test:

a.Assembling of master and prosthetic blocks.(Fig.38a)

b.Testing procedure by Universal testing machine.(Fig.38b)

XII.Final Qualitative analysis of the wear of surface of the attachments by stereo microscope.(Fig.39)

XIII.Data tabulation and statistical analysis.

I.Fabrication of custom-made plaster of paris block: (Fig.28)

A rectangular block of dimensions 60mm x 20mm x 10mm, (Fig.28) made of plaster of paris (Ramaraju Mills ltd.,India) (Fig.9) was custom made to serve as an index for the fabrication of wax blocks of similar dimensions and then to be converted into heat cure acrylic resin blocks of uniform dimensions to be used in this study.

II. Obtaining silicone putty index using custom-made plaster of paris Block: (Fig.29)

Addition silicone impression material of putty(Fig.5a) and light body consistencies (Aquasil,Denstply, Germany) (Fig.5b) were used for obtaining the index in a single step procedure.The putty was hand mixed with equal quantities of base and catalyst to obtain homogenous dough. Light body material in a cartridge was attached to the auto mixing gun (HeraeusKulzer,Dormagen, Switzerland)(Fig.5c).A spiral mixing tip(yellow 70mm , Adenta, USA) (Fig.5d) was attached to the cartridge tip and material was injected gently over the custom- made plaster block .The mixed putty was also placed over the plaster block and left undisturbed until set. After setting, the plaster block was removed from the index and the mold space area was inspected for defects and acceptability. The putty index thus obtained was used to fabricate the test samples of standardized dimensions for this study.(Fig.29)

III.Preparation of wax blocks using the index: (Fig.30a & 30b)

a. Master wax blocks(n=2)

b.Prosthetic wax blocks.(n=20)

Modeling wax (Hindustan manufacturer,Hyderabad) (Fig.6) was melted and poured into the mold space created by the putty and was allowed to cool. After the wax had completely hardened, the wax blocks were retrieved carefully and placed at room temperature. Twenty two such wax blocks of 60mm x 20mm x10mm dimensions were fabricated in which two blocks were used as master blocks and twenty blocks were used as prosthetic blocks to conduct the study.

Out of the two master blocks, in one block a height of 2mm was increased with wax on one half of the block exactly measured from the centre of the block. Similarly, out of the twenty prosthetic blocks, ten blocks were increased to a height of 2mm as it was done for the master blocks. (Fig.30a & 30b)

IV.Placement of implant analogs in the master wax blocks : (Fig.31a & 31b)

Two implant analogs with the diameter of 4mm and height of 12.7mm were positioned parallel to the insertion-removal path and to one another, on each of the master blocks using a dental surveyor. (seshin precison Ind.,co,korea.) (Fig.23)

The master blocks were placed on the surveying platform of the surveyor and stabilized (Fig.31a). The surveying platform was made parallel to the floor.The implant analogs were positioned into the wax blocks at a distance of 22mm from each other with equal distance from the centre of the block. The implant analogs were submerged into the wax block upto the crest module of the implant analogs (Fig.31b)

V.Fabrication of heat polymerized acrylic resin blocks: (Fig.32a & 32b)

(2 Master blocks with implant analogs and 20 Prosthetic blocks.)

The two master blocks with the implant analogs and the twenty prosthetic blocks were fabricated using heat polymerized acrylic resin.

a. **Flasking procedure:**

The fabricated wax blocks were invested in a denture flask using Type II dental plaster. A two pour technique was followed for flasking the wax specimens. Type II dental plaster was mixed with water using a stainless steel straight spatula in a rubber bowl (Classic, India) (Fig.14) and poured into the lubricated base portion of the denture flask. The wax blocks were placed into the denture flask. The number of samples per denture flask was restricted to a maximum of two to ensure adequate space between the samples. After the plaster had set, the separating medium was painted over the plaster surfaces, and the lubricated body of the flask was placed over the base. It was filled with a fresh mix of Type II dental plaster and the lid was closed. The denture flask (Star dental, India) (Fig.19) was tightened with a flask carrier and the excess plaster was removed.

b. **Dewaxing procedure :**

The plaster was allowed to harden for one hour before the denture flask was placed in a boiling water bath. The clamps were loosened and the flasks were placed in boiling water for fifteen minutes. The flasks were removed from the water and the appropriate segments of the flasks were carefully separated in a vertical direction to avoid fracture of the invested plaster. The softened wax was flushed out from the surface of the mold with hot water. Wax solvent and warm detergent solution were used to remove wax residues and oily films respectively. Finally the molds were flushed well with clean hot water. Both the halves of the flasks were placed slanting on the laboratory bench for few minutes to allow the water to drain completely. The flasks were allowed to cool completely prior to packing. After dewaxing , the rectangular mold spaces in the base of the denture flask were ready for packing of heat cure denture base acrylic resin.

c. **Packing of acrylic resin :**

A thin coating of separating medium (Fig.10)(DPI, India) was painted over the plaster surfaces. Clear heat polymerizing acrylic resin (DPI, India) (Fig.11) was mixed in a porcelain jar (Dentex store, India) (Fig.18) with a powder/liquid ratio as per the manufacturer’s instructions. The porcelain jar was closed with a lid until the mix reached the dough stage. Required quantity of acrylic resin was packed individually into each rectangular mold space. A thin acetate separator sheet was placed over the lower halves and then the upper halves were seated over them. Pressure was applied to allow excess resin to displace out of the denture flask.

Once the flask was fully closed, it was opened and the polyethylene sheet was removed and the excess was removed by using a sharp wax carver/ wax knife (Dentex store, India) (Fig.15) Trail closure with fresh polyethylene sheet is repeated till there is no longer apparent flash. The two halves of the flask were closed and the flask was placed under the bench press and tightened. The excess resin extruded from the flask was removed.

d. Curing procedure :

The packed denture flask were bench cured for sixty minutes as per the manufacturer's instructions and the flasks were removed from the bench press. The flasks were tightened under their respective flask carriers and placed in the acrylizer (Confident Dental Equipments limited, Bangalore, India) (Fig.24) for resin polymerization. A curing cycle of 74 degree Celsius for approximately two hours was carried out followed by increasing the temperature of the water bath to 100 degree Celsius and processing for one hour as per standard recommendations. This was followed for all the packed acrylic blocks.

e. Deflasking procedure :

After completion of the polymerization cycle, the flasks were removed from the water bath and bench cooled for 30 minutes and then kept under running tap water for 15 minutes. Following this , the deflasking was done . Excess plaster was removed from the blocks with a wax knife.

f. Finishing and Polishing:

Acrylic trimmers (Shofu, Japan) (Fig.20) were used to remove excess resin flash from the blocks. Emerypapers of grit sizes 100 and 120 respectively (Dentex store, India) (Fig.22) were used to smoothen the surface, mounted on a sandpaper mandrel (Dentex store, India) (Fig.21) attached to a dental lathe.(suguna industries ltd.,) (Fig.25). A total of twenty two heat polymerized acrylic blocks were obtained in a similar manner (Fig.32a & 32b).

VI.Placement of ball abutments to the implant analogs in the master blocks: (Fig.33)

The ball abutments of diameter 2.5 mm and height 2mm (Noris Dental implants) (Fig.2) were screwed into all the implant analogs embedded in the master blocks(Fig.33).

VII.Placement of metal housing with nylon cap insert over the ball abutment: (Fig.34)

Modelling wax was used to block the undercuts around the ball abutments in the master blocks. The metal housing of 5mm diameter and 3.2mm height along with nylon cap insert of standard retention (Noris Dental Implants) (Fig.3 & 4)was placed over the ball abutments for picking it up onto the prosthetic block (Fig.34).

VIII.Connecting the attachments to the prosthetic blocks:

(Fig.35a & 35b)

a. Recesses prepared in the prosthetic blocks to pick up the attachments:

The prosthetic blocks were now drilled with acrylic burs to create space for the metal housing with nylon cap insert.

b. Incorporation of attachments into the prosthetic blocks (Direct Pick up technique):

In order to prevent the acrylic adhesion of two blocks, a thin layer of separating medium (Tejpal pharma and surgical) (Fig.13) is applied on the master blocks. (Fig.35a) Clear autopolymerising acrylic resin (RR cold cure, DPI, India) (Fig.12) was poured into the space created and the metal housings with the nylon cap insert placed over the ball abutments in the master blocks were picked up in the prosthetic blocks. Upon setting, the master block with ball abutment was retrieved from the prosthetic blocks with the metal housing and nylon cap insert.(Fig.35b)Excess flash was removed using the acrylic burs. Same procedures were carried out for all the prosthetic blocks used in this study.

IX.Grouping of the test samples: (Fig:36)

Twenty prosthetic blocks thus obtained were divided into two groups of ten blocks each according to the height difference.

1. Group I (n =10) Test samples for the implant analogs placed at same height.
2. Group II (n = 10)Test samples for the implant analogs placed at different height.

X. Initial qualitative analysis of the wear of the surface of the attachments by stereo microscope: (Fig.37)

Each test sample was placed over the imaging platform of the stereo microscope (Fig.27) prior to retention testing. Images were captured in a computer controlled software system in 40x magnification at an object lens distance of about 13mm and the same magnification had been used for all the test samples (Fig.37).

XI. Retention Force Test: (Fig.38a & 38b)

a. **Assembling of master and prosthetic blocks.**

A total of twenty test samples were tested individually in the Universal testing machine (INSTRON 8874) (Fig.26) to measure the force required to separate the prosthetic block from the master block. Both the master block with ball abutment-implant analog assembly and the prosthetic test samples were positioned on the machine table and secured tightly into the upper and lower clamps of the universal testing machine. (Fig.38a)

b. Testing procedure by Universal testing machine:

Engagement and disengagement of the attachments were carried out at right angles to the horizontal level of the blocks. The testing machine was programmed to apply 1440 cycles of insertion – removals. Assuming that a patient removes and inserts his prosthesis four times a day, the retention force values were noted at baseline, after 360 cycles (simulating 3 months of clinical use), 720 cycles (simulating 6 months of clinical use), 1080 cycles (simulating 9 months of clinical use) and after 1440 cycles (simulating one year of clinical use) The test samples were kept moist with artificial saliva (Fig.8) throughout the testing as it acts as lubricant to simulate potential in-vivo conditions. The tests were conducted in an open room at room temperature.

The maximum vertical dislodging force required to separate the two blocks were recorded (in Newtons) at a crosshead speed of 50mm/min at a frequency of 0.8hz and the retention force values were obtained in a computer controlled software which is being attached to the testing machine.(Fig.38b)

XII. Final qualitative analysis of the wear of the surface of the attachments by stereo microscope: (Fig.39)

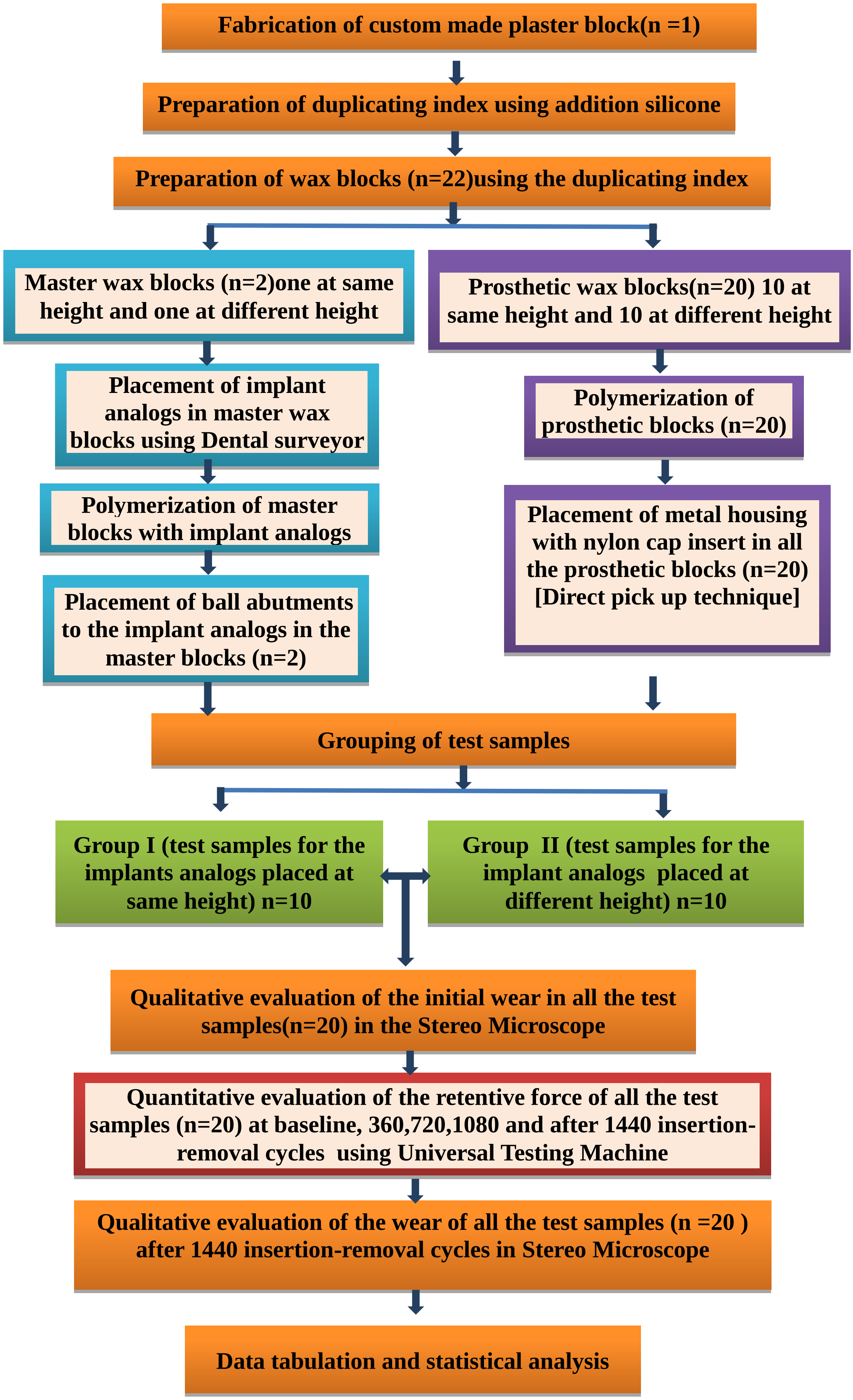
Each test sample was placed in the imaging platform of the stereo microscope after the completion of 1440(12 months) insertion- removal cycles at 40x magnification to assess the wear on the surface of the test samples . The image was captured in the computer controlled software attached to the system.

XIII. Data tabulation and statistical analysis:

The basic data obtained were tabulated using Microsoft Excel 10 (Microsoft, USA) and the mean and standard deviation were calculated. The data were subjected to statistical analysis for test of significance using SPSS Software version 20.0 (SPSS Software corp., munich, Germany).Retention force was analysed both within the group and between the test groups using Independent 't' test and Paired 't' test and a P value of <0.05 was considered statistically significant. Surface wear was assessed using descriptive analysis.

ANNEXURE I

METHODOLOGY OVERVIEW



ANNEXURE II

MATERIALS

Fig.1:Stainless steel implant analog-4mm diameter and height 12.7mm

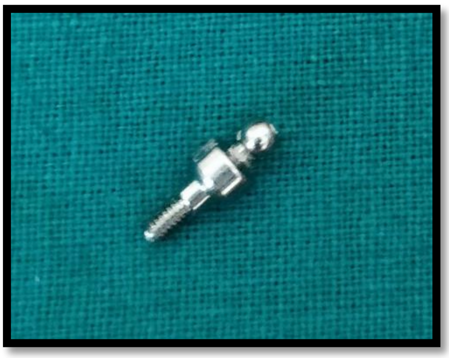


Fig.2: Titanium ball attachments -2.5mm diameter and 2mm height

Fig.3: Stainless steel metal housing – 5mm diameter and height 3.2mm

Fig.4: Cap insert – standard,white, nylon

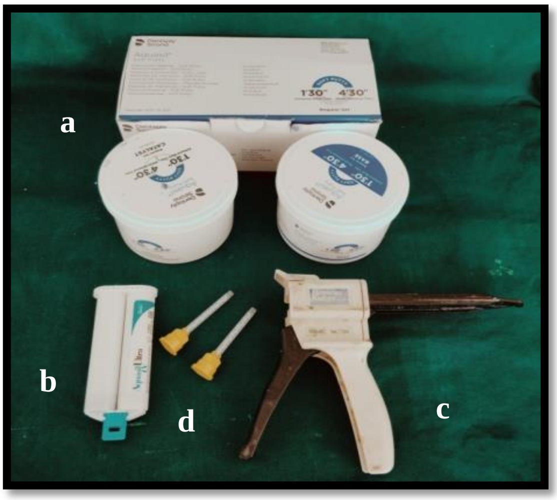


Fig.5a:Putty consistency polyvinyl siloxane impression material
5b:Light body consistency polyvinyl siloxane impressionmaterial
5c:Dispensing gun
5d: Auto mixing spiral

Fig.6 :Modelling wax

Fig.7: BP blade and handle

Fig.8.Artificial saliva

Fig.9.Plaster of paris

Fig.10: Cold mold seal

Fig.11: Clear heat polymerizing acrylic resin

Fig.12:Clear auto polymerizing acrylic resin

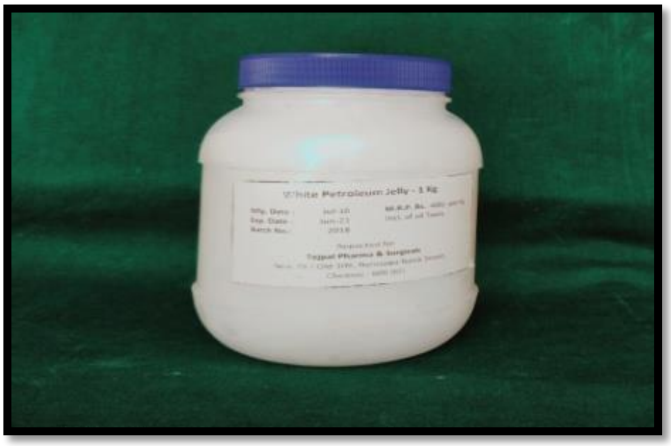


Fig.13:Vaseline

INSTRUMENTS USED FOR THE STUDY

Fig.14: Rubber bowl

Fig.15: Wax knife and wax carver

Fig.16: Metal scale

Fig.17: Bunsen burner

Fig.18:Porcelain mixing jar

Fig.19: Dental flask with clamp

Fig.20: Acrylic trimmers

Fig.21: Sand paper mandrel

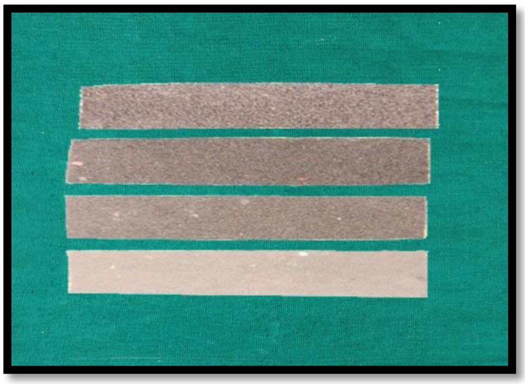


Fig.22: Emery Papers

EQUIPMENTS USED FOR THE STUDY

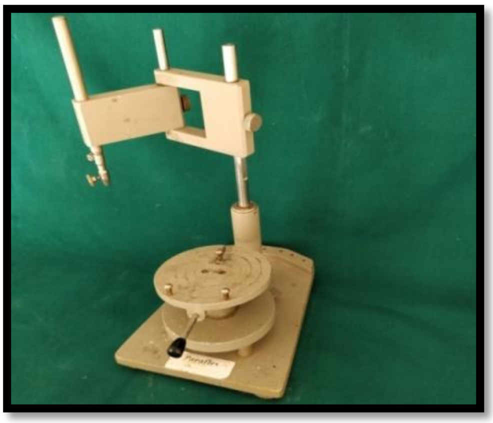


Fig.23: Dental surveyor

Fig.24: Acrylizer

Fig.25: Dental lathe

Fig.26: Universal testing machine

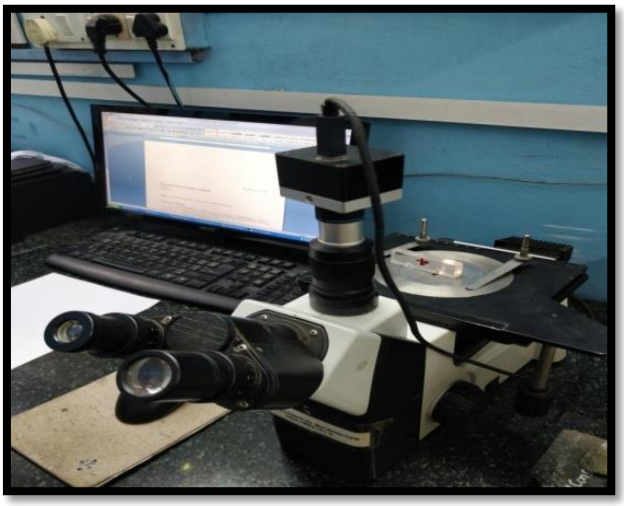


Fig.27:Stereo microscope

METHODOLOGY

I.FABRICATION OF CUSTOM MADE PLASTER OF PARIS BLOCK

Fig.28:Custom made plaster of parisblock

II.OBTAINING SILICONE PUTTY INDEX USING CUSTOM-MADE PLASTER OF PARIS BLOCK:

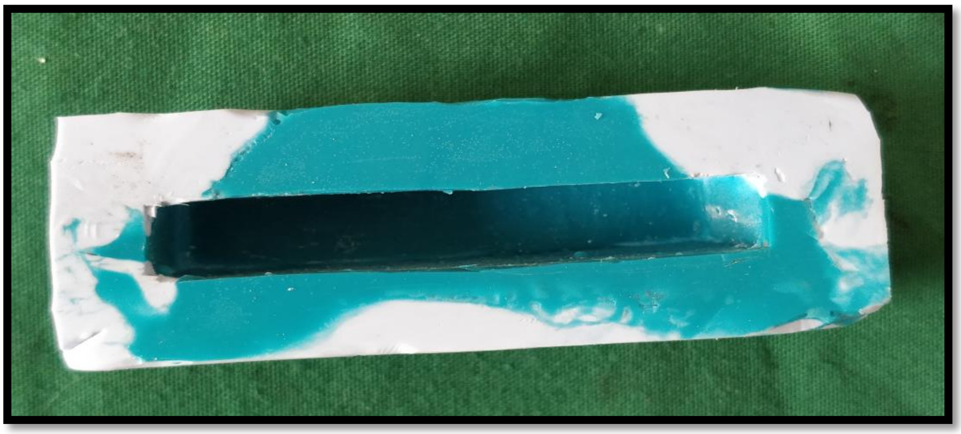


Fig.29: Putty index

III. PREPARATION OF WAX BLOCKS USING THE INDEX:

Fig.30a: Master wax blocks(n=2)

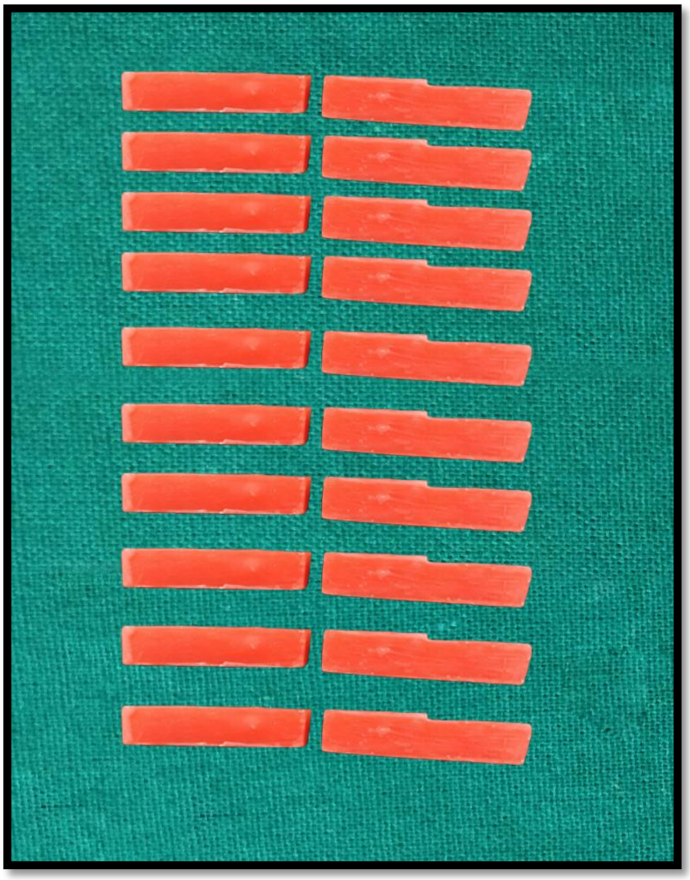


Fig.30b: Prosthetic wax blocks (n=20)

IV.PLACEMENT OF IMPLANT ANALOGS ON THE MASTER WAX BLOCKS

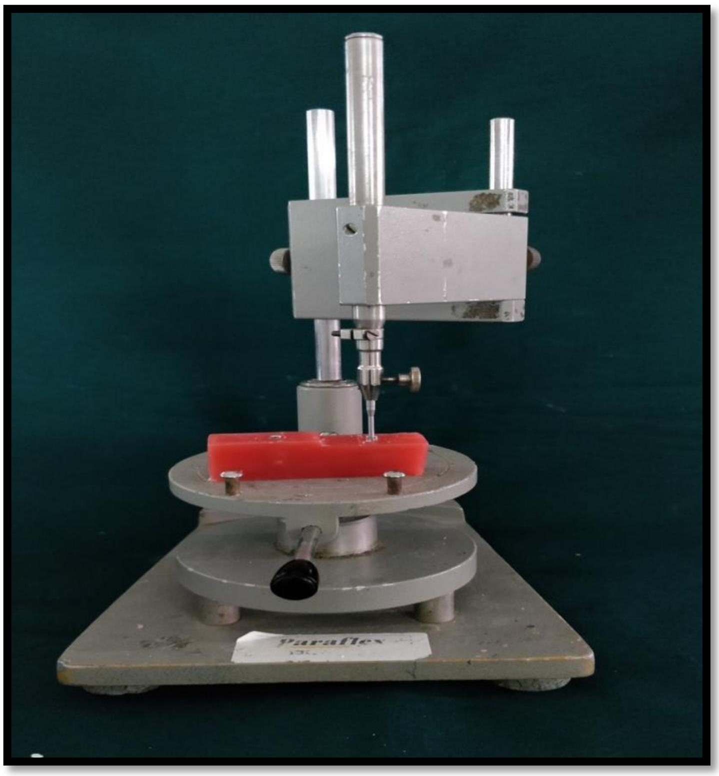


Fig.31a: Placing implant analogs

Fig.31b: wax blocks with implant analogs placed

V.FABRICATION OF HEAT POLYMERIZED ACRYLIC RESIN BLOCKS

Fig.32a:Master blocks with implant analogs

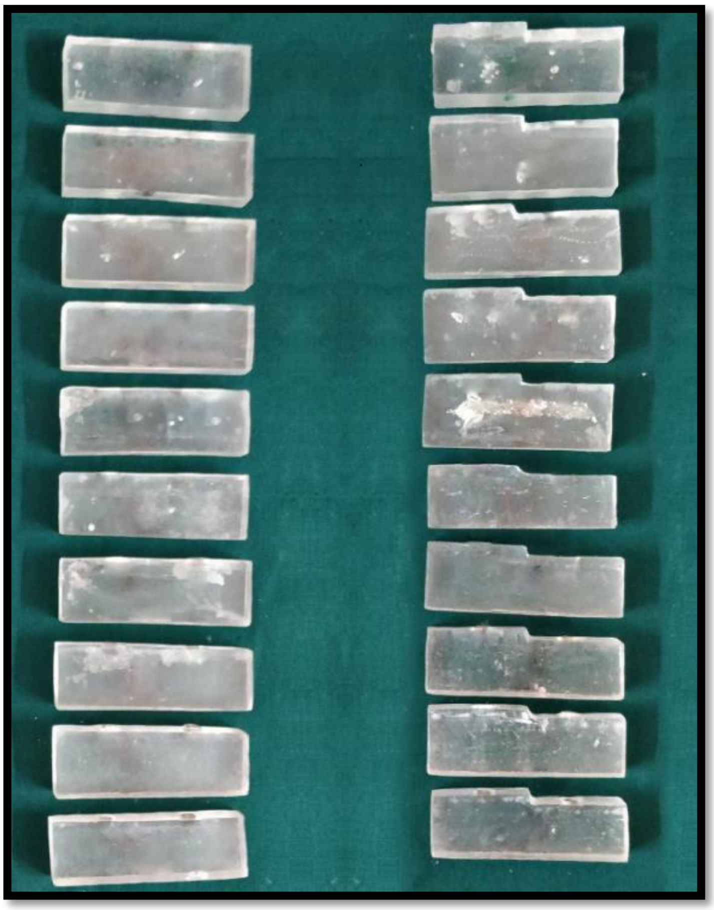


Fig.32b:Prosthetic blocks

VI.PLACEMENT OF BALL ABUTMENTS TO THE IMPLANT ANALOGS IN THE MASTER BLOCKS

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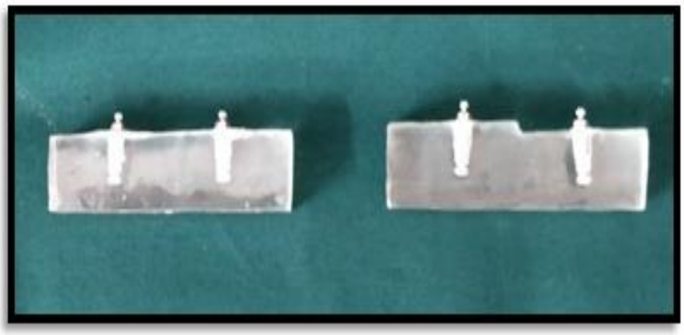


Fig.33: Ball abutments placed on the implant analogs

VII.PLACEMENT OF METAL HOUSING WITH NYLON CAP INSERT OVER THE BALL ABUTMENT.

Fig.34: Metal housing with nylon cap insert over the ball abutment

VIII.CONNECTING THE ATTACHMENTS TO THE PROSTHETIC BLOCKS

a. **Recesses prepared in the prosthetic blocks to pick up the attachments.**

Fig.35a:Recesses in the prosthetic blocks

b.Incorporation of attachments into the prosthetic blocks (Direct Pick up technique)

Fig..35b:prosthetic block with metal housing and nylon cap insert

XI.GROUPING OF THE TEST SAMPLES

Fig.36.Test samples for both group assembled

X..INITIAL QUALITATIVE ANALYSIS OF THE WEAR OF THE SURFACE OF THE ATTACHMENTS BY STEREO MICROSCOPE:

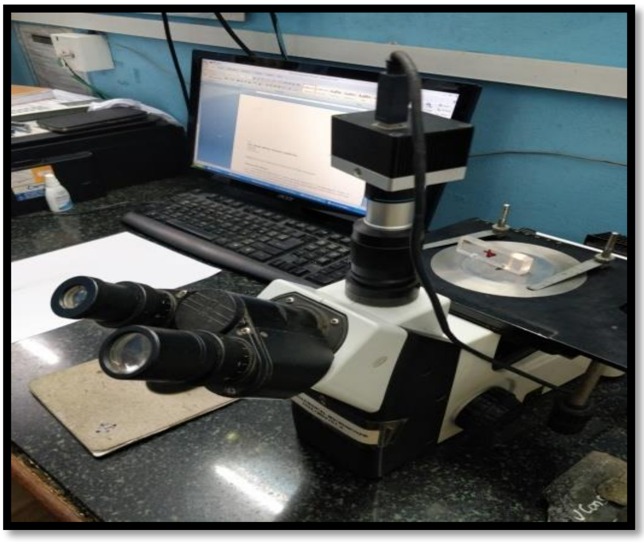


Fig.37:Stereo microscopic imaging

XI.RETENTION FORCE TEST

a. Assembling of master and prosthetic blocks

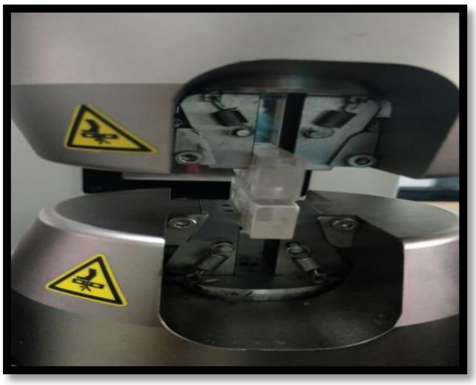


Fig.38a:Master and prosthetic blocks assembled in UTM

b.Testing procedure by Universal testing machine

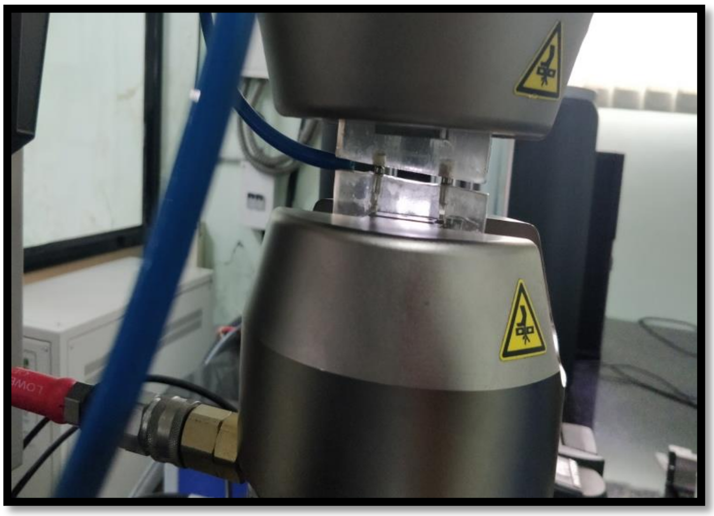


Fig.38b: Retention force testing

XII.FINAL QUALITATIVE ANALYSIS OF THE WEAR OF THE SURFACE OF THE ATTACHMENTS BY STEREO MICROSCOPE:

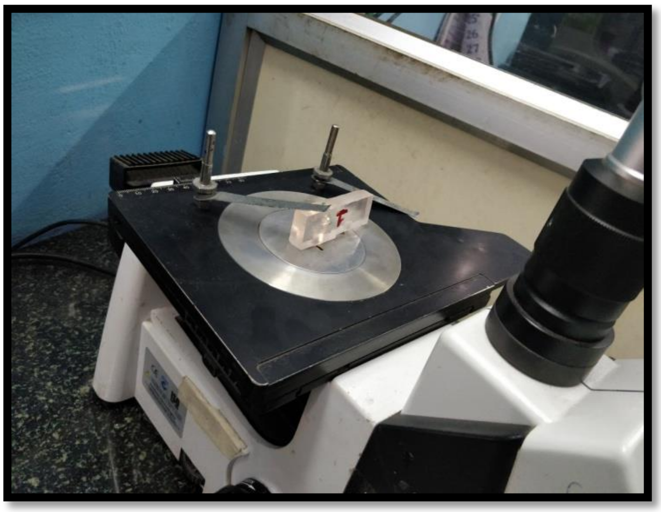


Fig.39:Stereo microscopic imaging

INITIAL QUALITATIVE ANALYSIS OF THE WEAR OF THE SURFACE OF THE ATTACHMENTS BY STEREO MICROSCOPE: (GROUP I)

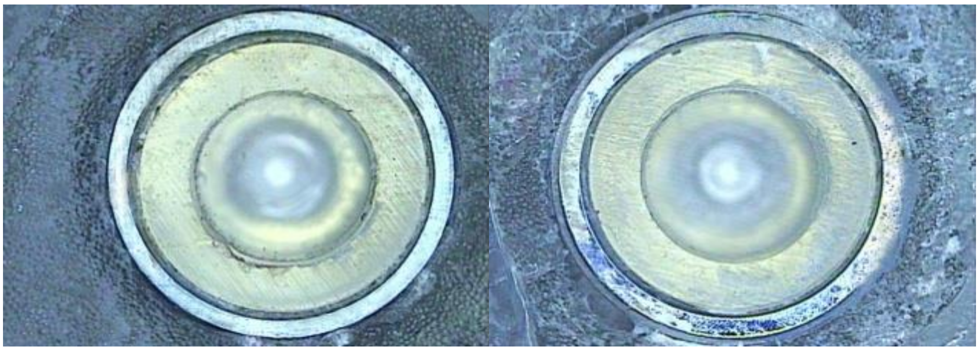


Fig.40a: Stereo microscopic picture of representative of Group I before retention force testing, observed under 40x magnification

Inference:

The nylon cap insert or the metal housing showed no deformations on their surface.

FINAL QUALITATIVE ANALYSIS OF THE WEAR OF THE SURFACE OF THE ATTACHMENTS BY STEREO MICROSCOPE (GROUP I)

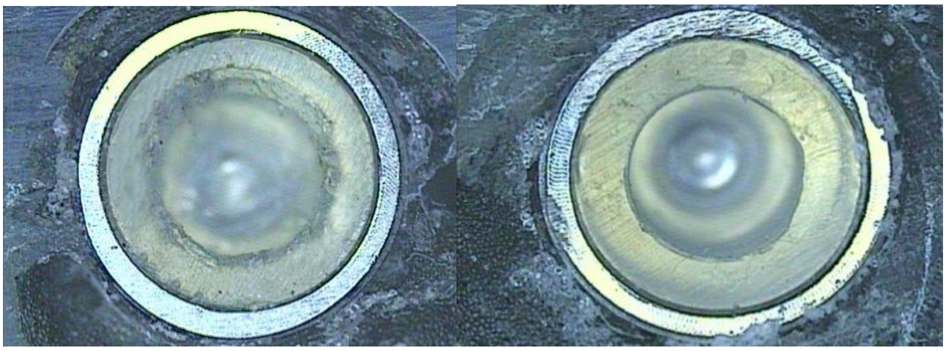


Fig.40b: Stereo microscopic picture of representative of Group I after retention force testing, observed under 40x magnification

Inference:

There were only minor changes observed on the metal housing. In the nylon cap insert, deformation was visible on both the attachments. These deformations were noticeable and observed both on the outer edges of the nylon cap insert and also on the inner retentive part.

INITIAL QUALITATIVE ANALYSIS OF THE WEAR OF THE SURFACE OF THE ATTACHMENTS BY STEREO MICROSCOPE: (GROUP II)

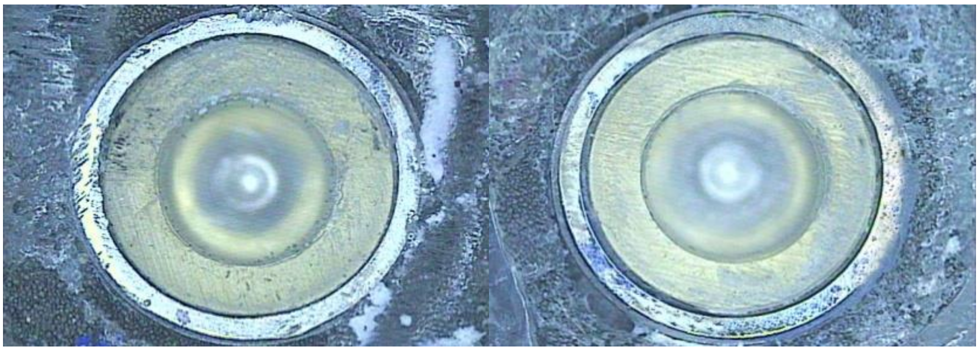


Fig. 41a: Stereo microscopic picture of representative of Group II before retention force testing, observed under 40x magnification

Inference:

The nylon cap insert or the metal housing showed no deformations on their surface.

FINAL QUALITATIVE ANALYSIS OF THE WEAR OF THE SURFACE OF THE ATTACHMENTS BY STEREO MICROSCOPE:

(GROUP II)

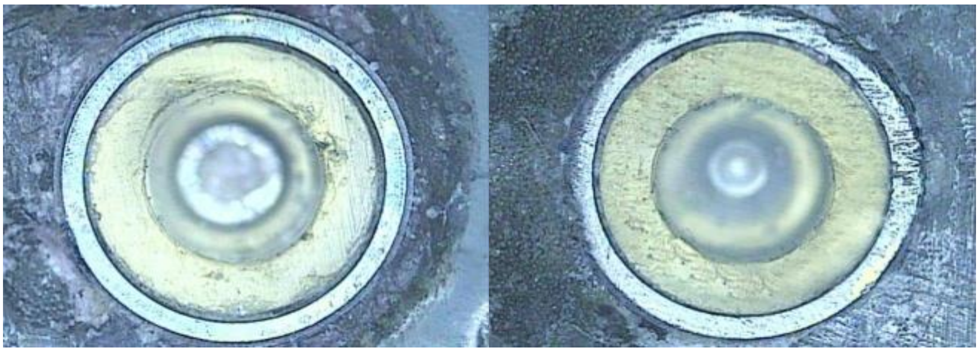


Fig.41b: Stereo microscopic picture of representative of Group II after retention force testing, observed under 40x magnification

Inference:

There were only minor changes observed on the metal housing. In the nylon cap insert, the deformations were noticeable. These deformations were observed on the outer edges of the nylon cap insert, the damage was superficial and the inner retentive part had no visible changes.

At the end of 1440 cycles of retention force testing, the overall surface deformations observed in Group II were lesser when compared with Group I.

Results

RESULTS

The present *in vitro* study was conducted to evaluate the the effect of implant height differences on the retention and wear behaviour of ball attachment system in mandibular two-implant over dentures.

22 wax blocks were fabricated and out of these 2 were used as master blocks and 20 as prosthetic blocks. In one master wax block, the implant analogs were placed at same height and in the other, the implant analogs were placed at different height. The master and prosthetic wax blocks were heat cured. The metal housing and the nylon cap insert were placed on the master block and the attachment assembly were transferred to prosthetic blocks by Direct pick up technique.

The prosthetic blocks were divided into two groups of 10 each. Group I had test samples for implant analogs placed at same height and Group II had test samples for implant analogs placed at different height. The prepared test samples were subjected to retention force testing using universal testing machine.

The retention force was tested at baseline, at 360 cycles(3 months), at 720 cycles (6 months), at 1080 cycles(9 months) and after 1440 cycles (12 months) simulating 1 year of clinical use. These were considered as the basic data and the respective means derived and are represented in Tables I-II and Graphs I-II. The data were subjected to statistical analysis using Independent sample ‘t’-test and Paired sample‘t’-test and represented in Tables III-V and Graph III. The percentage loss of retention forces were represented in Tables VI-VII and Graphs IV-V. Representative images showing surface wear obtained from stereo microscope of both the test groups are represented in Fig.40a-41b.

Tables and Graphs

TABLE 1: Retention force of overdenture specimen with ball attachment system retained by two implants placed in the same height at baseline, 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion removal cycles in Group I

Sample No	Retention force values (N)				
	At Baseline	360 cycles(3 months)	720 cycles(6 months)	1080 cycles(9 months)	1440 cycles(12 months)
1	27.54	24.52	23.63	21.513	19.55
2	25.53	23.93	23.01	20.87	18.42
3	25.41	24.6	22.43	21.14	18.45
4	24.83	22.31	22.01	20.14	19.65
5	24.54	23.01	21.13	21.0	20.51
6	23.72	22.54	22.0	20.72	17.34
7	24.14	23.92	23.01	22.88	21.06
8	29.63	24.40	22.91	21.43	20.20
9	22.41	21.8	20.75	20.03	18.14
10	24.54	23.83	23.61	20.95	19.44
Sample Mean	**24.73**	**23.49**	**22.46**	**21.07**	**19.28**

Inference: For Group I test samples, the sample mean obtained at baseline, 360, 720, 1080, and 1440 cycles were 24.73N, 23.49N, 22.46N, 21.07N, & 19.28N respectively.

TABLE 2: Retention force of overdenture specimen with ball attachment system retained by two implants placed in different height at baseline, 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion removal cycles in Group II

Sample No	**Retention force values (N)**				
	At Baseline	**360 cycles (3 months)**	**720 cycles(6 months)**	**1080 cycles(9 months)**	**1440 cycles (12 months)**
1	28.64	27.63	24.01	22.39	20.43
2	25.50	24.18	22.96	22.62	21.87
3	26.93	25.41	23.072	21.41	21.0
4	28.91	26.7	24.99	23.85	22.71
5	25.16	24.34	22.16	21.78	20.31
6	28.75	27.62	25.4	28.21	22.44
7	26.9	26.01	24.41	24.32	22.92
8	29.65	24.01	23.73	22.12	20.94
9	28.91	27.10	25.42	24.04	23.96
10	26.92	25.04	24.42	22.19	21.93
Sample Mean	**27.13**	**25.80**	**24.16**	**22.73**	**21.85**

Inference: For Group II test samples, the sample mean obtained at baseline, 360, 720, 1080 & 1440 cycles were 27.13N, 25.80N, 24.16N , 22.73N and 21.85N respectively.

TABLE 3: Comparison of the mean retention force of the test samples at baseline, 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion-removal cycles between Groups I & II using Independent sample 't'-test

Number of cycles	Groups	Sample No	Mean(N)	S.D	P Value
Base Line	G I	10	24.72	1.32	0.002**
	G II	10	27.12	1.63	
360	G I	10	23.48	1.00	<0.001**
	G II	10	25.80	1.40	
720	G I	10	22.45	0.98	0.002**
	G II	10	24.16	1.17	
1080	G I	10	21.07	0.79	0.001**
	G II	10	22.73	1.09	
1440	G I	10	19.28	1.16	<0.001**
	G II	10	21.85	1.17	

Inference:

- At baseline, retention force for Group II was found to be higher than Group I and this was statistically significant.
- At 360 cycles, retention force for Group II was found to be higher than Group I and this was statistically significant.
- At 720 cycles, retention force for Group II was found to behigher than Group I and this was statistically significant.
- At1080 cycles, retention force for Group II was found to be higher than Group I and this was statistically significant.
- At 1440 cycles, retention force for Group II was found to be higher than Group I and this was statistically significant.

TABLE 4: Comparison of the mean retention force of the test samples at baseline, 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion-removal cycles within Group I using Paired sample'*t*'-test.

Number of cycles	Mean(N)	S. D	P Value
0 360	24.73 23.48	1.33 1.00	0.002**
0 720	24.73 22.45	1.33 0.98	< 0.001**
0 1080	24.73 21.07	1.33 0.79	< 0.001**
0 1440	24.73 19.28	1.33 1.17	< 0.001**
360 720	23.49 22.45	1.00 0.98	0.001**
360 1080	23.49 21.07	1.00 0.79	< 0.001**
720 1440	22.46 19.28	0.98 1.17	< 0.001**
1080 1440	21.07 19.28	0.79 1.17	< 0.001**

Inference:

- From baseline to 360 cycles, retention force was found to be decreasing from baseline and this was statistically significant.
- From baseline to 720 cycles, retention force was found to be decreasing from baseline and this was statistically significant.
- From baseline to 1080 cycles, retention force was found to be decreasing from baseline and this was statistically significant.
- From baseline to 1440 cycles, retention force was found to be decreasing from baseline and this was statistically significant.
- From 360 cycles to720 cycles, retention force was found to be decreasing from 360 cycles and this was statistically significant.
- From 360 cycles to 1080 cycles, retention force was found to be decreasing from the 360 cycles and this was statistically significant.
- From 720 cycles to 1440 cycles, retention force was found to bedecreasing from 720 cycles and this was statistically significant.
- From 1080 cycles to 1440 cycles, retention force was found to be decreasing from 1080 cycles and this was statistically significant.

TABLE 5: Comparison of the mean retention force of the test samples at baseline, 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12months) insertion-removal cycles within Group II using Paired sample ‘t’-test.

Number of cycles	Mean(N)	S.D	P Value
0 360	27.01 25.80	1.64 1.41	< 0.001**
0 720	27.13 24.16	1.64 1.17	< 0.001**
0 1080	27.13 22.73	1.67 1.09	< 0.001**
0 1440	27.13 21.85	1.64 1.18	< 0.001**
360 720	25.80 24.16	1.41 1.17	0.001**
360 1080	24.80 22.73	1.41 1.09	< 0.001**
720 1440	24.16 21.85	1.17 1.18	< 0.001**
1080 1440	27.73 21.84	1.09 1.18	0.001**

Inference:

- From baseline to 360 cycles, retention force was found to be decreasing from baseline and this was statistically significant.
- From baseline to 720 cycles, retention force was found to be decreasing from baseline and this was statistically significant.
- From baseline to 1080 cycles, retention force was found to be decreasing from baseline and this was statistically significant.
- From baseline to 1440 cycles, retention force was found to be decreasing from baseline and this was statistically significant.
- From 360 cycles to 720 cycles, retention force was found to be decreasing from 360 cycles and this was statistically significant.
- From 360 cycles to 1080 cycles, retention force was found to be decreasing from the 360 cycles and this was statistically significant.
- From 720 cycles to 1440 cycles, retention force was found to be decreasing from 720 cycles and this was statistically significant.
- From 1080 cycles to 1440 cycles, retention force was found to be decreasing from 1080 cycles and this was statistically significant

- **TABLE 6:** Percentage loss of the mean retention force of the test samples at 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion- removal cycles in Group I

Number of cycles	Mean % retention	Percentage loss
0-360	95.08	4.92
0-720	90.90	9.1
0-1080	85.36	14.64
0-1440	78.10	21.9

Inference:

- In Group I, the percentage loss in the retention force at the end of 360 cycles was 4.92%.
- In Group I, the percentage loss in the retention force at the end of 720 cycles was 9.1%.
- In Group I, the percentage loss in the retention force at the end of 1080 cycles was 14.64%.
- In Group I, the percentage loss in the retention force at the end of 1440 cycles was 21.9%.

TABLE 7: Percentage loss of the mean retention force of the test samples at 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion removal cycles in Group II

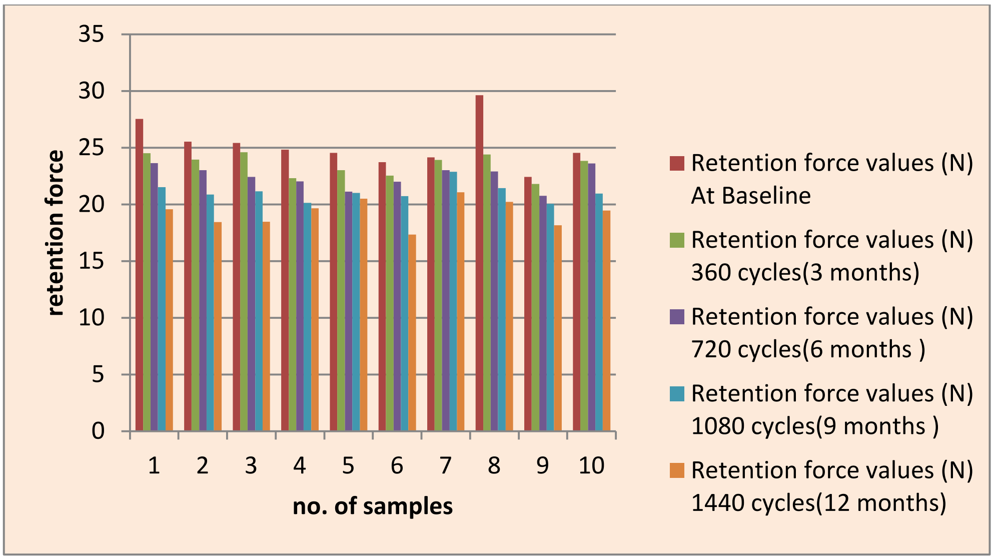
Number of cycles	**Mean % retention**	**Percentage loss**
0-360	95.16	4.84
0-720	89.20	10.8
0-1080	83.94	16.1
0-1440	80.67	19.33

Inference:

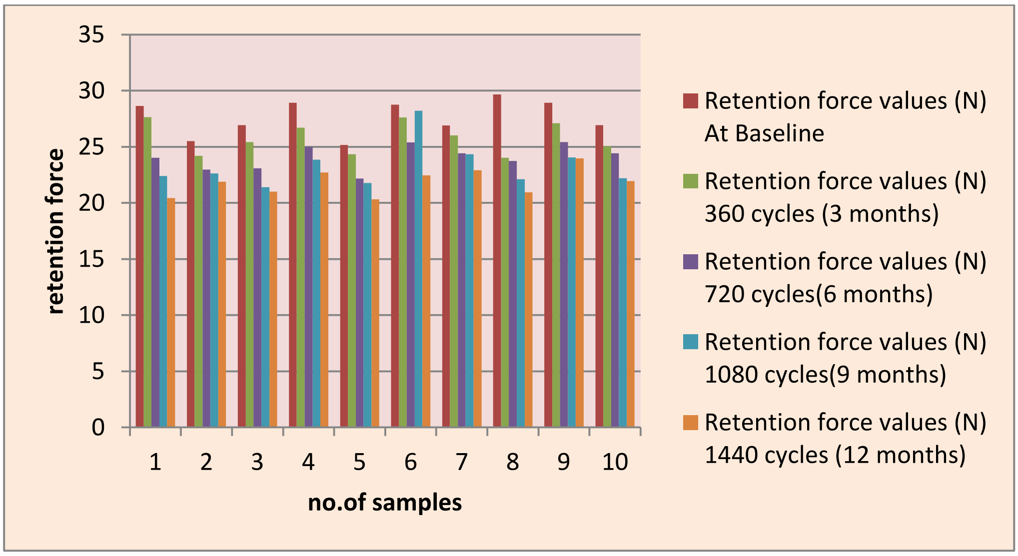
- In Group II, the percentage loss in the retention force at the end of 360 cycles was 4.84%.
- In Group II, the percentage loss in the retention force at the end of 720 cycles was 10.8%.
- In Group II, the percentage loss in the retention force at the end of 1080 cycles was 16.1%.
- In Group II, the percentage loss in the retention force at the end of 1440 cycles was 19.33%.

ANNEXURE III

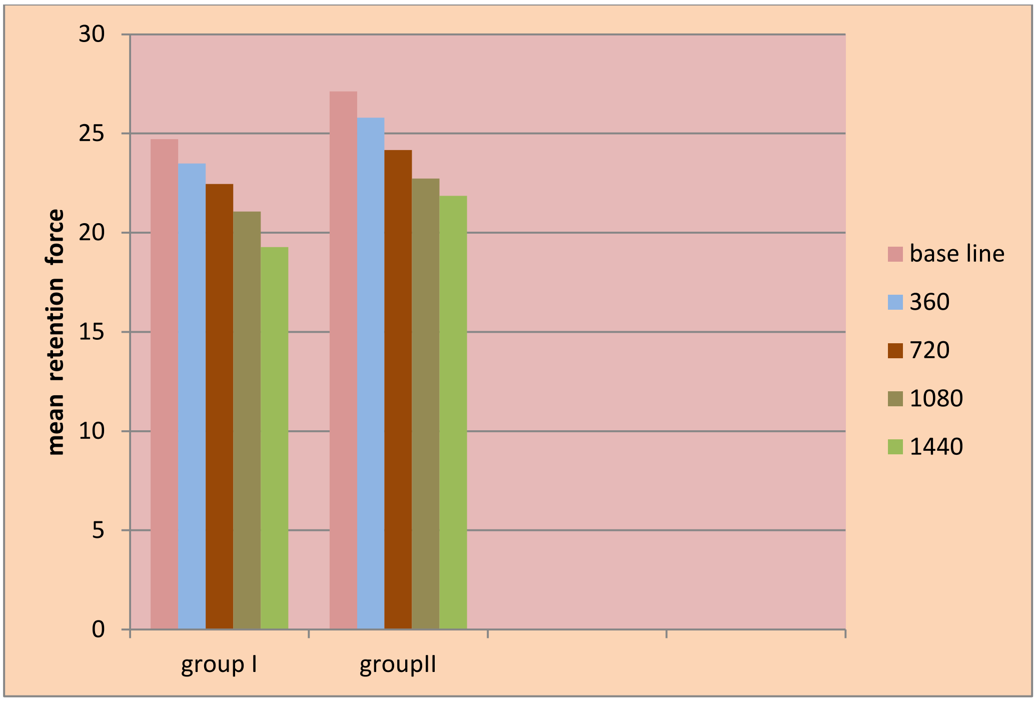
Graph 1: Retention force of overdenture specimen with ball attachment system retained by two implants placed in the same height at baseline, 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion removal cycles in Group I.



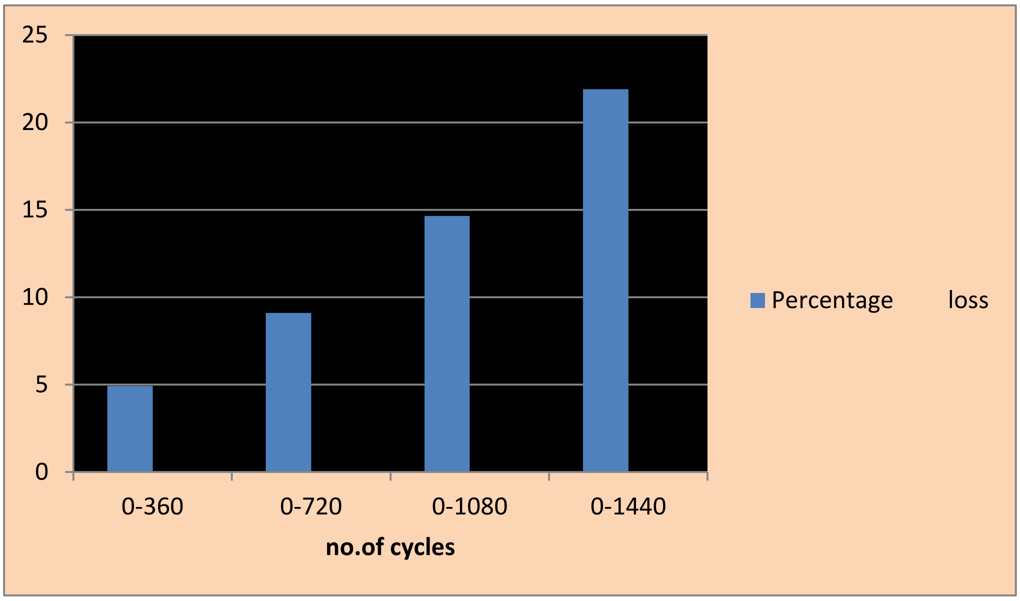
Graph 2: Retention force of overdenture specimen with ball attachment system retained by two implants placed in different height at baseline, 360 (3 months), 720(6 months), 1080 (9 months) and after 1440 (12 months) insertion removal cycles in Group II.



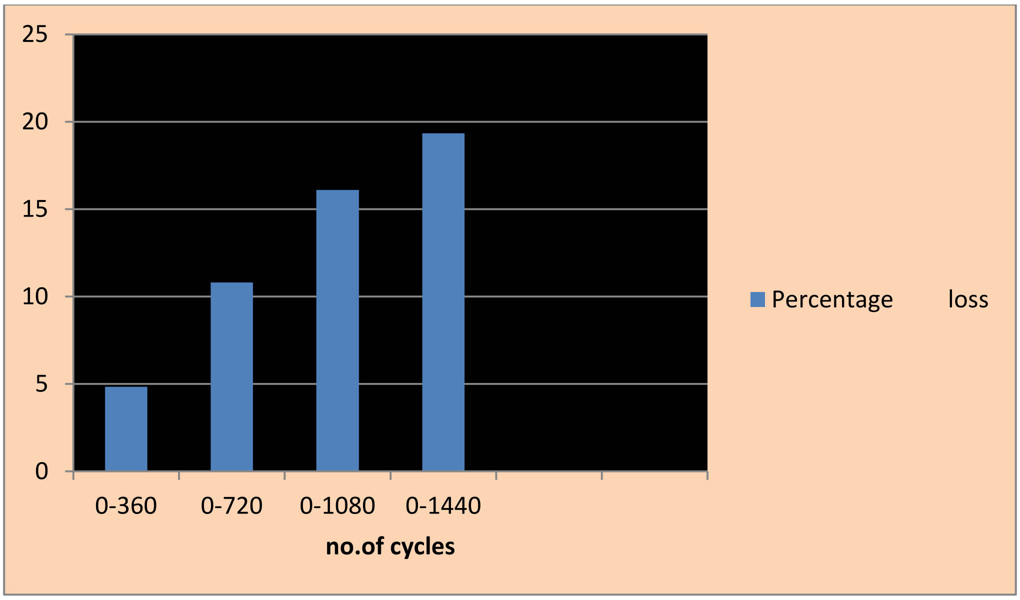
Graph 3: Comparison of the mean retention force of the test samples at baseline, 360 (3 months), 720 (6 months) 1080 (9 months) and after 1440 (12 months) insertion removal cycles between Groups I & II using Independent sample 't'-test



GRAPH 4: Percentage loss of the mean retention force of the test samples at 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion removal cycles in Group I



GRAPH.5: Percentage loss of the mean retention force of the test samples at 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion removal cycles in Group II



Discussion

DISCUSSION

The present in vitro study evaluated the effect of implant height differences on the retention and wear behaviour of ball attachment system in mandibular two-implant over dentures.

Complete edentulism is the most common dental problem associated with the elderly people.[34,42] It is the condition with a poor health outcome and it reduces the quality of life of the affected people.[2] The prosthetic management of the completely edentulous patients is a most challenging procedure in dentistry.[2,28] The classical and standard treatment option for completely edentulous patients is the conventional complete denture. [2,24,34]

The conventional complete dentures are provided to restore the chewing efficiency,to improve the speech and the overall oral function in patients. The common problems associated with the conventional dentures includes poor stability and retention of the prosthesis, pain during mastication and difficulty in speech.[24,26,34] This is because the bone resorption after tooth loss, decreases retention and stability of dentures by altering their bio mechanical behaviour.[9] These considerations are most commonly seen in the edentulous mandible where bone resorption and muscle dynamics act more intensely than maxilla.[9] The speed and direction of alveolar bone loss is not same in maxilla and mandible. Rapid and more dramatic changes take place in the mandible [32.]

Cancellous bone is ideally designed to absorb and dissipate the forces that is subjected to it. The maxillary residual ridge is often broader, flatter, and more cancellous than the mandibular ridge.[32] Trabeculae in upper arch are oriented parallel to the direction of compression deformation, which allows maximum resistance to deformation. The stronger these trabeculae are, the greater is the resistance offered. Due to these anatomical variations, the differences were observed in the residual ridge resorption pattern of the upper and lower jaw.[32]

Due to this reason, complete denture wearers are often satisfied with their maxillary denture but most of them have issues with the mandibular denture because of the lack of retention and stability due to the severely resorbed ridges.[19,34] Mandibular overdentures retained by remaining natural teeth roots were seem to be avoiding problems associated with conventional complete dentures thereby improving the retention and stability.[26,31] The poor retention and stability could be managed either by means of fixed prosthesis using multiple implants or by the fabrication of implant supported overdentures.[4,24,26,34]

With the invention of implant supported overdentures, the patient factors of esthetics, phonetics and maintenance of optimum oral health and hygiene have been markedly increased even in the case of patients with poor neuromuscular coordination.[4,17,34] With a high implant success rates in mandible (97.7- 100%) and also in maxillae (87.5-96.4%), implant supported overdentures have been considered as a good alternative to conventional complete dentures.[28]

Annual alveolar ridge height reduction was approximately 0.4mm in the edentulous anterior mandible, while the long-term resorption of bone under an implant overdenture prosthesis may remain 0.1mm annually.[31,32,34] Using multiple implants in overdentures showed only slight increase in retention,stability, and occlusal equilibration when compared with overdentures having only two implants.[31]

Also patients with atrophic ridge conditions preclude the use of more number of implants. Two-implant supported mandibular overdentures offers the same efficiency as with fixed implant supported mandibular prostheses along with simplicity and relatively low cost.[31] Therefore the two-implant supported mandibular overdentures have been considered as the gold standard of care for edentulous patients by many.[4,19,26] A consensus statement from McGill University and British Society for the study of Prosthetic Dentistry determined that a two-implant overdenture should be the first choice of treatment for an edentulous mandible.[12,24]

Retention is considered as a key factor for patient satisfaction in removable prosthodontics.[10,31] It is defined as the force that resists withdrawal along the path of insertion and stabilizes the overdenture during function. There is a strong evidence that retention is of great importance for patient's satisfaction.[30]

The three important factors involved in optimal overdenture treatment plan are retention, support and stability. The combination of these factors can lead to overall acceptance and satisfaction of the removable prosthesis and it is difficult to seclude one factor from the other.[33]

The success of an implant supported overdenture primarily depends on the retentive capacity of its attachment part to provide a long-term functionality.[5,19] Although many parameters like proper border extensions, adhesion, neuro muscular control contribute to the retention of mandibular overdentures, still attachments in the overdentures have a major role.[31]

An ideal attachment system should provide a high and stable retentive force with a reduced lateral force to the implant, not only in the parallel positioning of the implant, but also in the inclination of implant when subjected to recurrent dislodging.[43] In implant overdenture attachments , 'the release period' defines the time required by the attachment system to lose its retention or disengage from the abutment when it undergoes forced separation.[11] This parameter has clinical significance both in retention and stability of the prosthesis during function. However, this also serve as a safety mechanism unique to that particular attachment system used.[11]

There were different attachment systems to retain implant-supported overdentures, divided mainly into two groups. They were splinted and unsplinted attachments.[5,24,36] Bar attachments are included in splinted systems, whereas unsplinted systems include magnets, ball types, and locators.[5,19,36] A combination of metal-metal or metal-plastic /nylon contacts is generally used in an attachment system.[5,19]

Some authors used bar-type attachments in overdentures. However, these attachments are not so economical, more complex to use, and needs more restorative space than the unsplinted attachments.[36] Therefore, the ball attachments came into use in overdentures frequently. It is one of the easiest and cheapest attachments for overdenture among all those.[4,24,34,41] It is well known for its resiliency for providing free movements in both horizontal and vertical directions. Also, the specific design of the ball attachments helps in limiting its resiliency. [24] Maeda et al[43] has given that the ball attachment had a better retentive force and bracing effects with the help of its large dimensions provided in the attachment. A study by Godfredson et al[41] reported that the two-implant supported overdentures with bar or ball attachment, the technical problems and the repair was 20 times more in bar system than the ball –type attachment .

The retention and the attachment's longevity have been reported as a most common clinical problem in many in vitro studies. Lot of studies evaluated the retentive force of different attachment systems simulating different periods of clinical use in two-implant mandibular overdentures.[4,19,26,35] Some studies were done between ball, bar and locator[35] also between ball, locator and magnetic attachments to comparatively evaluate the retentive capacity of them.[43]

There were also some in vitro studies on the evaluation of the retentive force of two commercially available ball attachment systems.[23] In addition to this, few studies were done on the evaluation of retention of attachments by placing implants at different angulations.[10,43] Some studies comparing the retentive capacity of different color codings of a single attachment system have also been reported.[10]

One of the main reason for retention loss is the deformations seen on the surface of the components of the attachment system as a result of wear.[4,26] Wear is defined as a ''loss of material from a surface caused by a mechanical action alone or through a combination of chemical and mechanical actions.'' [12] Among all implant restorations, the wear of overdenture attachments has been identified as the most common (33%) prosthodontic complication.[42]

According to Wichmann and Kuntze,[17] attachment systems suffer wear during movements of insertion and removal as well as during functional load.

This wear is due to friction between the base and attachment leading to decreased retention values. This occurrence has also been mentioned in many previous studies. Many studies have evaluated the effects of the wear on the attachment systems and also on the amount of wear resulted during retention testing.[17]

Olivier Fromentin et al. in 2011 studied the clinical wear of ball attachments after one, three, and eight years and reported that the highest rate of wear was seen after three years of clinical use.[41]

Ideally, implants must be placed parallel to each other and to the path of insertion of the prosthesis, perpendicular to the occlusal plane, at a similar distance from the midline and at the same height.[18] Unfavorable implant placement is common in clinical practice because of the difficulty in placing implants in the most desirable positions due to poor bone quality or variations in anatomical structures.[24]

The positioning of the implant attachments plays a vital role in two-implant overdentures, because in the presence of pathological overloading the bone around the implants becomes deformed and resorbs due to the excessive stress and strain gradients.[24] This situation leads to incompatibility in the components and microfracture of the implant. In order to overcome these issues and to increase the success rates of the implant-supported dentures, implants should be placed in the same height and at optimum location.[24]

However, in the completely edentulous patient, alveolar bone can be resorbed with different types of resorption patterns which may affect the symmetry of the bone height in the anterior mandible.[24,32] Resorption rate of the residual alveolar ridge differs from one person to other and at different sites and times in the same patient.[32] All these factors may affect the symmetry of the bone height in the mandible. In those cases, implants could be placed at different heights according to the literatures.[24]

Few studies observed the retentive force of attachments in two-implant overdentures at different abutment heights.[37] However, these in vitro studies have not studied about different implant heights. Ozan O and Ramoglu S [24] evaluated the stress distribution in the peri-implant site and on attachments by placing implants in different height levels using 3D Finite Element Analysis. However, studies comparatively evaluating retention and wear of attachments in two-implant overdentures with implants placed at different heights are lacking.

In light of the above, the aim of the present in vitro study was to evaluate the effect of implant height differences on the retention and wear behaviour of ball attachment system in mandibular two-implant over dentures The null hypothesis of the present study was that implant height differences does not affect the retention and wear behaviour of the two-implant overdenture attachments.

All the steps discussed in the methodology for test sample preparation were adopted from the methodology described in the previous studies.[4,19,26] All the procedures were performed by a single operator in order to avoid errors by multiple operators. Various authors have used test blocks of varying dimensions for testing the retention force values.[4,26] In the present study, a customized plaster block was employed to serve as a template for obtaining acrylic blocks of standardized dimensions as mentioned in the previous study.[44] Addition silicone was used as indexing material[4] since the material can withstand repeated handling without undergoing distortion or tearing.

Noris implant analogs, ball abutments and attachment system comprising of metal housing with nylon cap insert were selected. These implant analogs were placed using the surveyor to ensure the parallelism between the implants as mentioned in previous studies.[4,26] The parallel placement of implants enables complete insertion of the prosthesis by engaging the attachments in order to prevent the wear of the attachments.[18] The two implant analogs were placed at a distance of 22mm apart from each other,[4] as it has been reported that the natural canines are separated by the same distance.[9,26] According to several authors, inter-implant distance is a factor influencing the retentive strength of attachments.[9]

Retentive force was measured previously by various methods like dental mastication simulator, [10,37]micro material testing machine,[30,31] cyclic fatigue machine (load cell),[9] CS-dental testing machine,[5] Imada device[16,18] and universal testing machine (UTM)[4,18,26] The retention properties of the test samples were measured in the present study using the Universal testing machine (8874 model), to replicate the vertical separation of the denture from the mouth.[26] It has been used as the valuable and reliable instrument to test the dislodging forces in vitro previously by many authors.[4,26]

Different number of cycles had been used in different studies, like 10,000 cycles equivalent to a corresponding time of use of 9 years,[19] 5500 cycles (3 years),[19,26] 14,600 cycles (which represents 10 years of clinical use)[19] and 1080 cycles (1 year)[4] In the present study , the test samples were subjected to 1440 insertion-removal cycles which corresponds to one year of clinical usage of dentures,[4] considering an average of four removals per day in accordance with previous studies[17,19] and the retention force was measured at baseline, 360, 720, 1080 and 1440 insertion-removal cycles.

Previous studies have employed demineralised water, saline solution and 0.9% isotonic sodium chloride solution maintained at 22 degree celcius to simulate in vivo conditions during their testing procedure.[19] In the present study, artificial saliva was maintained throughout the testing procedure at room temperature to simulate a wet oral environment, also to act as a protective and lubricant layer between the components of the attachments used as mentioned in some previous studies.[25,26]

Many studies evaluated the retentive force of overdenture attachments in different dislodgment speeds (900 cm/min to 0.5 mm/min domain). (0.5mm/min to 150 mm/sec), 120 mm/min.[18] Sarnat proposed a crosshead speed of 50mm/min[18] and said that it is as close to the speed of the movement of real overdenture removal from its retention elements when vertical force is applied[4,26] and therefore it was used in the present study. The retention force test was carried out with the above mentioned parameters.

In the present study, the test samples have been divided into two groups, Group I and Group II. Group I had test samples for the implant analogs placed at same height and Group II had test samples for the implant analogs placed at different height. The retention force obtained for all the test samples for both Group I and Group II were tabulated and statistically analysed.

In addition to the retentive forces, wear was also evaluated in many previous studies by various methods like scanning electron microscopy,[10,21] co-ordinate measuring machine,[41] digital light microscopy[26] and stereo microscopy.[36,42] In the present study, the qualitative analysis of the wear of the test samples was done using stereo microscope under 40x magnification which was previously used in many studies.[26,36]

The results of the present study showed the following, For Group I test samples, the sample mean of the retention force obtained at baseline, 360, 720, 1080, and 1440 cycles were 24.73N, 23.49 N, 22.46N, 21.07N, & 19.28N respectively.

For Group II test samples, the sample mean of the retention force obtained at baseline, 360, 720, 1080 & 1440 cycles were 27.13N, 25.80N, 24.16 N, 22.73N& 21.85 N respectively

On comparing the mean retention force between Group I and Group II, at baseline , the retention force for Group II was found to be higher than Group I and this was statistically significant (0.002**). At 360 cycles , the retention force for Group II was found to be higher than Group I and this was statistically significant (<0.001**). At 720 cycles, the retention force for Group II was found to be higher than Group I and this was statistically significant (0.002**). At 1080 cycles, the retention force for Group II was found to be higher than Group I and this was statistically significant (0.001**). At 1440 cycles, the retention force for Group II was found to be higher than Group I and this was statistically significant(<0.001**).

On overall comparison of the mean retention force, statistically significant difference was observed between the two test groups. Group II exhibited significantly higher retention force values compared to Group I.

Ozan O and Ramoglu S have evaluated the stress distribution on the peri-implant bone and on different attachments by placing implants at different height levels in mandibular two-implant overdentures and concluded that decreased stress values in the peri-implant bone were obtained with the models with increased height difference.[24] Ying et al studied about the influence of the height of the stud attachments and concluded that the greater height of the stud attachments exerted the highest lateral force on the implant and greatest denture displacement.[44]

A study on evaluation of retentive force of different locator abutment heights done by Sia et al,[37] showed that groups with 0mm(32.3N), 2mm(37.1N), 4mm (41.9N) height difference have lower retention than the group with 6mm(53.6 N) height difference. This was due to increased friction or rotational path of dislodgement. In the attachments with 6mm height difference between each other, it was also reported that during testing, separation of the 2 attachments from the 2 abutments did not occur at the same time, but often one followed the other. Thus, he concluded that the different height levels of the abutments might have provided a rotational path of dislodgement, thereby requiring higher retentive force.[37]

In the present study, implants placed at different height showed a significantly higher retention values than the implants at same height. This might be due to the different height levels of the implant which have provided rotational path of dislodgement thereby requiring higher retention force comparatively which correlates with the study done by Sia et al with different abutment heights which was mentioned above. The reason for this situation need to be explored further in future studies. Studies similar in design with the present study are lacking in literature to enable further comparisons.

On comparing the mean retention force in Group I from baseline to 360 cycles, the retention force was found to be decreasing from the baseline and this was statistically significant(0.002**), from baseline to 720 cycles, the retention force was found to be decreasing from the baseline and this was statistically significant(<0.001**), from baseline to 1080 cycles , the retention force was found to be decreasing from the baseline and this was statistically significant(<0.001**), from baseline to 1440 cycles, the retention force value was found to be decreasing from the baseline and this was statistically significant(<0.001**), from 360 cycles to 720 cycles, the retention force value was found to be decreasing from 360 cycles and this was statistically significant(0.001**), from 360 cycles to 1080 cycles, the retention force was found to be decreasing from the 360 cycles and this was statistically significant(<0.001**), from 720 cycles to 1440 cycles, the retention force was found to be decreasing from 720 cycles and this was statistically significant.(<0.001**).On comparing the mean retention force values in Group I from 1080 cycles to 1440 cycles , the retention force was found to be decreasing from 1080 cycles and this was statistically significant(<0.001**).

On comparing the mean retention force in Group II from baseline to 360 cycles, the retention force was found to be decreasing from the baseline and this was statistically significant(<0.001**), from baseline to 720 cycles, the retention force was found to be decreasing from the baseline and this was statistically significant(<0.001**), from baseline to 1080 cycles , the retention force was found to be decreasing from the baseline and this was statistically significant(<0.001**), from baseline to 1440 cycles, the retention force was found to be decreasing from the baseline and this was statistically significant(<0.001**), from 360 cycles to 720 cycles, the retention force was found to be decreasing from 360 cycles and this was statistically significant(0.001**), from 360 cycles to 1080 cycles, the retention force was found to be decreasing from the 360 cycles and this was statistically significant(<0.001**), from 720 cycles to 1440 cycles, the retention force was found to be decreasing from 720 cycles and this was statistically significant(<0.001**), from 1080 cycles to 1440 cycles, the retention force was found to be decreasing from 1080 cycles and this was statistically significant(0.001**).

According to previous studies, most of the attachment systems showed a common trend toward a reduction in the retention force.[4,33] Memarian et al.,[23] evaluated the retentive properties of two commercially available ball attachments(straumann and Rhein83) and showed there was gradual and significant decrease in the retention force after 5500 cycles. Arora and mittal[4] evaluated the retention force values of different attachments like locator, ball/O-Ring and ball/nylon-cap simulating 1 year of clinical usage and shown that all attachments lose retention over time. Therefore, repeated insertion-removal cycles led to a gradual and continuous loss of retention as mentioned in the above studies.

In the present study, regardless of the high retention values at the beginning of the study in both the groups, there is gradual decrease of retention values which is in agreement with the above mentioned previous studies.

Some studies showed 18.7% loss of retention of O-rings after simulated 30 months of clinical use and in other study, it was 16.6% retention loss after simulated 6 months of clinical use and 57.1% loss after 24 months.[42] In a study by Arora and Mittal,[4] the retention force values of different attachments like locator,ball/O-Ring and ball/nylon-cap simulating 1 year of clinical usages were evaluated and retention loss was maximum for ball/o-ring(76.6%) and minimum for ball/nylon cap (18.4%) and locator (20.2%). In the present study, the overall percentage loss of retention force after 1440 cycles in Group I and Group II was 21.9 % and 19.33 % respectively. This study has also revealed that there was percentage loss which was slightly higher than those observed in previous studies. This might be due to variations in the company of the nylon cap employed or the height difference of the implant analogs. However, this needs to be evaluated further in the future studies.

Many previous studies have reported that, the retention force of about 5 to 7 N was enough to stabilize the overdentures during function[4,17,26] All the test samples of both groups have retention force values more than the above mentioned value and therefore it was considered satisfactory to stabilize the overdenture. However, reduced retention characteristic may be desirable in some patients with poor manual dexterity,[4] who may have difficulty during insertion and removal of overdenture. Therefore ,under such specific situations, matching the retentive level of the attachments to the physical condition and required needs of the patient should be considered while planning treatment .

Gamborena et al[12] revealed distinct wear patterns on ERA attachments characterized by the distortion of the plastic patrices, whereas the metallic matrices appeared unchanged under microscopic measurements. Similar observations were also reported with four ball-attachment systems. In many previous studies, the wear of components of ball attachments was found to be responsible for a decrease in the retention of the attachments, and leading to the eventual fracture of the attachment components.[12] In the present study, stereo microscopic images showed wear on the surface of the attachments of all the test samples of both groups at the end of the study after completion of 1440 insertion removal cycles which is in line with the above mentioned studies.

Also, the implants placed at different height have shown less wear deformations than the implants placed at same height. Therefore it was concluded that, the implants placed at different height had less wear which corroborates with the greater retention obtained with it and the implants placed at same height had more wear which corroborates with the lesser retention obtained.

From the results obtained and within the limitations of the present study, it can be concluded that , the implant height difference has its effect on both the retention and wear of the overdenture attachments used. Thus, the null hypothesis of this study is not validated.

The present study had some limitations. Factors like parafunctions, temperature of saliva and its composition, products used for cleansing dentures as well as the presence of food residues may influence the parameters tested above which are difficult to simulate *in vitro*. Under clinical conditions, the forces exerted on the attachments are more complex, with tridimensional forces often occurring. Further studies are needed to evaluate the retention force by placing implants at various height differences, simulating longer periods of clinical usage, by comparing single implants or two implants or by comparing different attachment systems. Further studies incorporating the above are recommended to add merit to the findings obtained with the present study.

Conclusion

CONCLUSION

The following conclusions were drawn from the results obtained in the present in vitro study, which was conducted to evaluate the effect of implant height differences on the retention and wear behaviour of ball attachment system in mandibular two-implant over dentures.

1. On evaluating the retention force of overdenture specimen with ball attachment system retained by two implants placed in the same height (Group I) and at different height (Group II) at baseline, 360 (3 months), 720 (6 months), 1080 (9 months) and after 1440 (12 months) insertion- removal cycles, the basic mean values obtained are as follows:
   - For Group I test samples, the sample mean obtained at baseline, 360, 720, 1080, and 1440 cycles were 24.73N, 23.49N, 22.46N, 21.07N and 19.28N respectively.
   - For Group II test samples, the sample mean obtained at baseline, 360, 720, 1080 & 1440 cycles were 27.13N, 25.80N, 24.16N, 22.73N and 21.85N respectively
2. On comparing the mean retention force between Group I and Group II:
   - At baseline, the retention force for Group II was found to be higher than Group I and this was statistically significant(0.002**). At 360 cycles, the retention force for Group II was found to be higher than Group I and this was

found to be statistically significant (<0.001**). At 720 cycles, the retention force for Group II was found to be higher than Group I and this was statistically significant(0.002**). At 1080 cycles ,the retention force for Group II was found to be higher than Group I and this was statistically significant (0.001**) and after 1440 cycles, the retention force for Group II was found to be higher than Group I and this was statistically significant(<0.001**).

- On overall comparison of the mean retention force, statistically significant difference was observed between the two test groups, Group II exhibited significantly higher retention force compared to Group I.

3. On comparing the retention force within GROUP I:

- From baseline to 360 cycles, the retention force was found to be decreasing from the baseline and this was statistically significant(0.002**). From baseline to 720 cycles, the retention force was found to be decreasing from the baseline and this was statistically significant(<0.001**). From baseline to 1080 cycles, the retention force was found to be decreasing from the baseline and this was statistically significant(<0.001**). From baseline to 1440 cycles, the retention force was found to be decreasing from the baseline and this was statistically significant(<0.001**). From 360 cycles to 720 cycles, the retention force was found to be decreasing from 360 cycles and this was statistically significant(0.001**). From 360 cycles to 1080 cycles, the retention force was found to be decreasing from the 360 cycles and this was statistically significant(<0.001**). From 720 cycles to 1440 cycles, the retention force was found to be decreasing from 720 cycles and this was statistically significant (<0.001**). From 1080 cycles to 1440 cycles, the retention force was found to be decreasing from 1080 cycles and this was statistically significant(<0.001**).

- On overall comparison of the mean retention force within Group I, the retention force was found to be decreasing from baseline to 1440 cycles and this was statistically significant.

4. On comparing the retention force within GROUP II:

- From baseline to 360 cycles, the retention force was decreasing from the baseline and this was found to be statistically significant(<0.001**) From baseline to 720 cycles, the retention force was decreasing found to be from the baseline and this was statistically significant(<0.001**). From baseline to 1080 cycles , the retention force was found to be decreasing from the baseline and this was statistically significant(<0.001**). From baseline to 1440 cycles, the retention force was found to be decreasing from the baseline and this was statistically significant(<0.001**). From 360 cycles to 720 cycles, the retention force was found to be decreasing from 360 cycles and this was statistically significant(0.001**). From 360 cycles to 1080 cycles, the retention force was found to be decreasing from the 360 cycles and this was statistically significant(<0.001**). From 720 cycles to 1440 cycles, the retention force was found to be decreasing from 720 cycles and this was statistically significant(<0.001**). From 1080 cycles to 1440 cycles, the retention force was decreasing from 1080 cycles and this was found to be statistically significant(0.001**).

- On overall comparison of the mean retention force within Group II, the retention force was found to be decreasing from baseline till 1440 cycles and this was statistically significant

5. The Percentage loss of the mean retention force of the test samples for Group I at 360 (3 months), 720 (6 months) 1080 (9 months) and after 1440 (12 months) insertion-removal cycles were 4.92, 9.1, 14.64 and 21.9% respectively.
6. The Percentage loss of the mean retention force of the test samples for Group II at 360 (3 months), 720 (6 months) 1080 (9 months) and after 1440 (12 months) insertion-removal cycles were 4.84, 10.8, 16.1, 19.33% respectively.

- At the end of the study, the overall percentage of retention loss after 1440 cycles in Group I and Group II was 21.9 % and 19.33 % respectively.

7. The qualitative evaluation of the surface wear of all the test samples under stereo microscope under 40x magnification revealed the following:

   In Group I:

   - The nylon cap insert or the metal housing showed no deformations on their surface initially before the retention force testing.
   - At the end of 1440 insertion-removal cycles, there were only minor changes observed on the metal housing. In the nylon cap insert, deformation was visible on both the attachments. These deformations were noticeable and observed both on the outer edges of the nylon cap insert and also on the inner retentive part.

   In Group II:

   - The nylon cap insert or the metal housing showed no deformations on their surface.
   - At the end of 1440 insertion-removal cycles, there were only minor changes observed on the metal housing. In the nylon cap insert, the deformations were noticeable. These deformations were observed on the outer edges of the nylon cap insert , the

damage was superficial and the inner retentive part has no visible changes.

- The overall surface deformations observed in Group II were lesser when compared with Group I at the end of 1440 cycles of retention force testing.

Summary

SUMMARY

The present in vitro study was conducted to evaluate the effect of implant height differences on the retention and wear behaviour of ball attachment system in mandibular two-implant over dentures.

Twenty two wax blocks were fabricated and out of these two were used as master blocks and twenty were used as prosthetic blocks. Two implant analogs were placed in each master wax block. In one master wax block, the implant analogs were placed at same height and in the other, the implant analogs were placed at different height. The master and prosthetic wax blocks were heat cured. The metal housing and nylon cap insert were placed on the master block and the attachment assembly were transferred to prosthetic blocks by Direct pick up technique.

The prosthetic blocks were divided into two groups of ten each. Group I had test samples for the implant analogs placed at same height and Group II had test samples for the implant analogs placed at different height. The master block and the prosthetic block were then assembled and subjected to retention force test. The retention force was tested at baseline, at 360 cycles(3 months), 720 cycles(6 months), 1080 cycles(9 months) and after 1440 cycles(12 months) simulating 1 year of clinical use, using universal testing machine at a crosshead speed of 55mm/min in the presence of artificial saliva.

The wear of the surface of all the test samples were qualitatively assessed initially and after completing 1440 insertion-removal cycles using stereo microscope. Retention force values of both the test groups were obtained. The data was tabulated and analysed using Independent sample ‘t’-test and Paired sample‘t’-test.

At the end of the study after 1440 cycles, the two-implant overdenture attachments prepared from implant analogs placed at different height had significantly higher retention force than with the same height. The present study revealed that the retention force was decreasing from the initial level to twelve months of simulated clinical use. The percentage of loss of retention is also increasing from the initial placement of the attachment till the end of the study. Qualitative analysis of the overdenture attachment has revealed that there was continuous wear of the attachment from the initial period till the completion of the study. On comparison, the wear of the attachment was more in Group I compared to Group II which corroborates with the decrease in retention with Group I during usage and the less wear with Group II corroborates with the higher retention with Group II.

In the present study, the retention force values obtained after mechanical cycling exceeded the minimum level required to keep an overdenture in place which is 5 to 7 N as described in the literature. So, the implants can be placed at same height or at different height depending on the clinical condition of the patients requiring the implant overdenture treatment.

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ANNEXURE IV

PLAGIARISM REPORT

URKUND

Urkund Analysis Result

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